

# THE SCIENCE OF STAR WARS

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NEW! MONSTER TRUCKS

# HOW IT WORKS

SCIENCE ENVIRONMENT



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## WHAT MAKES A MAMMAL?

Find out what connects us to our closest animal relatives



## 10 MIND-BLOWING SPACE DISCOVERIES

How astronomy changed our understanding of the universe



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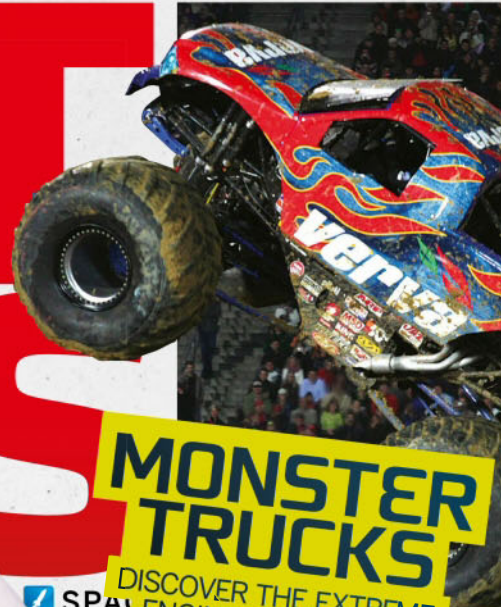


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# STAR WARS™

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# WELCOME

The magazine that feeds minds!



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With *The Last Jedi* about to be released, what better time for us to investigate the ever-thinner line between fantasy and reality in *Star Wars*? When *A New Hope* was

released in 1977, tech like speeders and laser weapons were only possible in the galaxy far, far away... but as our tech has advanced, we're getting closer to seeing them in the here and now.

Back in reality, this month we reveal how trauma departments work. Find out how these amazing teams perform life-saving work over in our science section.

Also this issue, we discover what makes us mammals, take a wild ride with monster trucks, unearth a titanic dinosaur and show you how to build your own robot.

*Jackie* **Jackie Snowden**  
Editor

*"Star Wars is science fiction, but that doesn't mean you can't throw in a bit of science fact too..."*

The science of *Star Wars*, page 14

## Meet the team...



**Charlie G**  
Production Editor

Ever since I first read about the Trojan Wars I've always wondered whether the famous Trojan Horse ever really existed. Find out on page 78.



**Baljeet**  
Research Editor

The top 10 space discoveries are literally out of this world! I was fascinated to learn about the first exoplanets found. Find out more on page 54.



**Charlie E**  
Staff Writer

I was so excited to find out about the new heat-sensitive colour changing hair dyes that are now available. Find out how they work on page 47!



**Scott**  
Staff Writer

Nebulae are some of the universe's most striking oddities. The Pencil Nebula is more like a space doodle than a gas cloud! Find out more on page 58.



**Duncan**  
Senior Art Editor

I've always wondered how monster trucks fly off ramps! They're so large it's amazing they even get off the ground! Learn how they do it on page 60.



**Laurie**  
Studio Designer

Our emergency services go above and beyond their duties as medics. Turn to page 38 to learn about their work and what it takes to save a life.

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## Meet the experts...



#### Jonny O'Callaghan

Jonny is on a quest to discover the physics of *The Force* and the tech behind the X-wing. Discover the ratio of science to fiction of a galaxy far, far away...



#### Jodie Tyley

Former *HIW* Editor Jodie reveals why so many Roman structures are still standing after thousands of years and then busts one of history's biggest myths over on page 78.



#### James Horton

James explains how to build your very own robot over in our tech section. Find out which skills and abilities are important to consider when creating your ultimate droid companion.



#### Stephen Ashby

In our How To section this issue, Steve guides you step-by-step through some science experiments you can try out at home. Let us know how you get on — we'd love to see your photos!



#### Laura Mears

This month, Laura reveals how ambulance crews, accident and emergency departments and trauma teams work together to save lives. Find out more on page 38.

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## The Bloodhound speeds through its first test run

HIW's Scott Dutfield visited Newquay to witness the jet-powered car in action



A crowd of around 3,500 spectators gathered at Cornwall Airport Newquay to witness the first test run of the car working towards breaking the world land speed record. The Bloodhound SSC resembles more of a fighter jet than a car; a Eurofighter Typhoon fighter jet to be precise. A Eurojet EJ200 engine provides the Bloodhound with 90,000 Newton's of thrust. The ground shook under the immense power of the Bloodhound as it raced down the 2.7-kilometre runway to reach its 322-kilometre-per-hour target. Not only did the Bloodhound meet its target, but it flew past it, reaching 338 kilometres per hour in eight seconds.

The test run was a familiar experience for designated driver Andy Green, having sat in the high-speed cockpit of the current record-holding car (the Thrust SSC) 20 years ago. Together they officially broke the sound barrier and achieved a record speed of around 1,227.985 kilometres per hour. With a successful test run under its belt, the Bloodhound is on track to reach its goal of reaching (or exceeding) 1,000 miles (1,609 kilometres) per hour. The record-breaking run is due to take place in 2018 in the Hakskeen Pan in South Africa.



### Eurojet EJ200 jet engine

Approximately half of the Bloodhound's thrust will be generated by its EJ200 engine, the same type of engine used in Eurofighter Typhoon fighter jets.

While some modifications have been made to make sure the engine is compatible for use in the car rather than in a plane, the way it produces thrust is the same. Air is sucked into the engine and compressed, then fuel is added and the mixture combusts and expands.

It is this expansion that forces the exhaust out of the rear nozzle, thereby generating thrust. Housed

in the back of the Bloodhound, the engine weighs in at one ton and could suck out the air from an average house in just three seconds! In order to reach 1,609 kilometres per hour the Bloodhound will need around 400 litres of jet fuel and 800 litres of rocket oxidiser.

In addition to the jet engine, a Nammo rocket engine will also contribute to generating the Bloodhound's thrust, while a Jaguar supercharged V8 engine will provide auxiliary power to drive the rocket oxidiser pump.

Three EJ200 engines have been loaned to the Bloodhound Project by the UK's Ministry of Defence



Some of the team behind the Bloodhound project



Royal Air Force fighter pilot Andy Green drove the car during its test run and will also be driving during the record attempt in 2018



## Q&A Scott caught up with the director of the Bloodhound SSC project, Richard Noble

### How is the event going?

It's an amazing time for us — this project has been really hard. Britain is a funny place at the moment, we don't have much in the way of confidence, but here we are setting out to build a 1,000-mile-per-hour [1,609-kilometre-per-hour] car. The Bloodhound is running well, and suddenly people are realising this car has got real value.


### What inspired the project?

When the Americans decided they were going to challenge our supersonic land speed record, Andy Green and I said that we were going to take them on. We thought about how fast the Americans would plan to go, probably to 800 miles [1,287 kilometres] per hour, so we are going to go to 1,000 miles [1,609 kilometres] per hour. It was as simple as that. We were highly ambitious and we had no idea of the sheer scale of what we were taking on, but we now have the car and we have got the research done.



# IT'S HARDER TO HEAL AT NIGHT

Researchers have found that our body clocks allow us to repair injuries better in the day

 Circadian rhythm, better known as our body clock, is the cycle that keeps us ticking. During a 24-hour cycle it helps to drive multiple processes in the body, from hormone secretion and sleeping patterns to metabolism. And researchers at the Medical Research Council (MRC) Laboratory of Molecular Biology in Cambridge have discovered that this cycle can affect the healing of wounds such as cuts and burns.

Dr John O'Neill, the senior author of the study, said, "This is the first time that the circadian clock within individual skin cells has been shown to determine how effectively they respond to injuries."

The study found that, on average, burns that occurred at night took 60 per cent longer to heal than burns that happened during the body clock daytime cycle. Nighttime burns (sustained between 8pm and 8am) healed around 28 days later as opposed to that of 17 days if a burn was sustained during the day (between 8am and 8pm). The study drew these conclusions after analysing data from 118 patient records from all major burns units in England and Wales.

The reasoning behind the differences in healing time is due to how long it takes for skin cells to move to the site of the wound and begin repairs, a process that occurs more quickly during the daytime. This is driven by increased

activity of the proteins within the cell, in particular actin filaments, which act like a muscle within the cell.

In a statement, Dr Ned Hoyle, the lead author of the study, said, "We've shown that the daily cycles in our body clock control how well cells can repair damaged tissue by affecting an essential protein called actin. Efficient repair of our skin is critical to preventing infection, and when healing goes wrong wounds can become chronic or excessive scarring can occur. Further research into the link between body clocks and wound healing may help us to develop drugs that prevent defective wound healing or even help us to improve surgery outcomes."



Scientists have found that the time of day a wound occurs can affect its healing time

## How much faster do daytime injuries heal?

Time of day the injury occurs	Time for wound to heal to 95%
00:00-03:59	39 days
04:00-07:59	31 days
08:00-11:59	15 days
12:00-15:59	20 days
16:00-19:59	16 days
20:00-23:59	23 days

**358**

The average number of litter items found per kilometre of seabed in 2016

**61%**

The proportion of British adults who spend two or more hours per day on their phones

**800**

The estimated population of the newly identified Tapanuli orangutan species

**10  
metres**

The estimated wingspan of the recently discovered Pterosaur fossil in Mongolia

## Eating the middle man

Scientists have discovered a new way for predators to catch prey



Known as kleptopredation, researchers at the University of Portsmouth have found that sea slugs benefit from waiting for their meal to finish its meal.

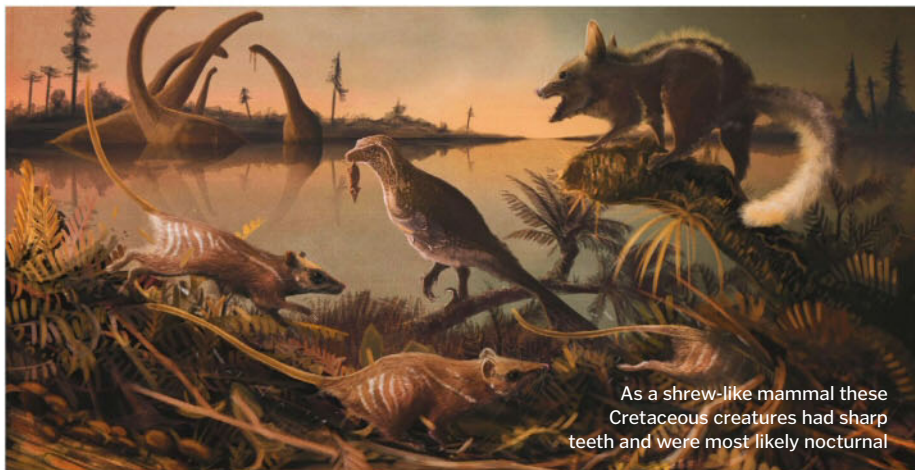
Nudibranchs are a family of sea slugs that live at the bottom of the ocean and prefer polyps that have recently filled up on plankton. These filter-feeding polyps are found on hydroid colonies, a distant relative of coral reefs. This

predator-prey relationship has also been suggested to increase the hydroid's life span.

"We have some great results here that rewrite the text book on the way these creatures forage and interact with their environment," says lead researcher Dr Trevor Wills.



It has been suggested that nudibranchs could help sustain hydroid colonies



As a shrew-like mammal these Cretaceous creatures had sharp teeth and were most likely nocturnal

## Evidence of the oldest mammal is discovered

Described as descendants of humans, these fossils resemble more mouse than man



Found on the Jurassic Coast in Dorset, fossilised teeth have been discovered dating back 145 million years. Lead author Dr Steve Sweetman believes the specimens come from a small rat-like creature: "The teeth are of a type so highly evolved that I realised straight away I was looking at

[the] remains of Early Cretaceous mammals that more closely resembled those that lived during the latest Cretaceous — some 60 million years later in geological history." Scientists have also said that these fossils belong to the evolutionary line that leads all the way up to humankind.



In Sweden a meteorite lands once every two years

## A true antique

A 4-billion-year-old meteorite has sold for a figure that's out of this world



Sold on the online auction site Catawiki, the meteorite went for an impressive £14,436 (approximately \$19,000). This chunk of space was discovered in Sweden during the early 20th century and was previously held in the world-renowned Muonionalusta meteorite collection. The price per gram of meteorites has been estimated to be around 40 times more than the equivalent price of gold. With a weight of 26.5 kilograms, this meteorite is a falling gold mine.

© Gabriella Luongo; Alamy; Mark Witton; Stefan Marjoram

## Jack Ashby

**How It Works'** Charlie Evans speaks to the renowned zoologist about his career

**J**ack Ashby has worked as the Grant Museum manager since 2011, having graduated from Cambridge University with a zoology degree and originally joined the museum as the learning and access manager. In his new book, *Animal Kingdom*, he compiles a selection of 100 natural history specimens, telling their 100 stories: from the incredible feats of evolution displayed in insect mimicry — where non-poisonous butterflies mimic their poisonous counterparts to protect themselves from predation — to the mysterious purpose of the narwhal's tusk.

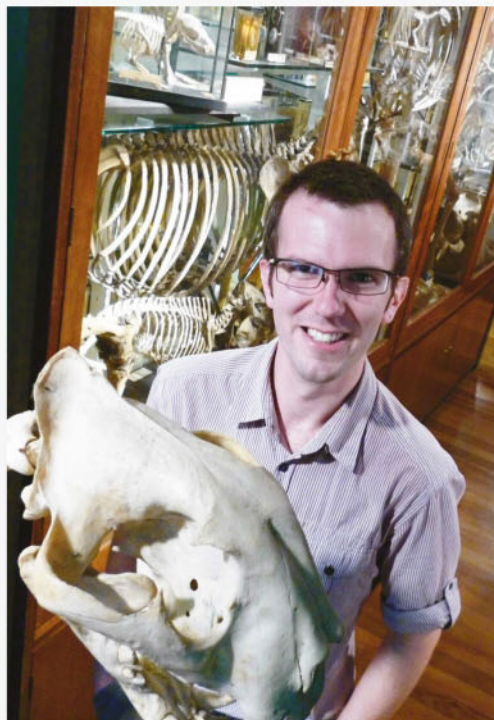
The book explores 600 million years of natural history, with examples from across the animal kingdom, including the duck-billed platypus, electric eel and brain-controlling parasitic fungi. We spoke with him about his love for zoology, the museum he manages and his new book.

### **What is The Grant Museum of Zoology, and what do you do there?**

My job is to find interesting ways to engage both the public and universities with the museum, as well as trying to bring universities' research into the museum and engage the public by using objects. We house approximately 68,000 specimens; it's relatively small, but we have a huge amount on display.

We have more specimens on display than the Natural History Museum, at least of animals — we don't have minerals or plants. The museum dates back to the 1820s; it's one of the earliest natural history museums in the country. It still looks reasonably traditional but that's quite deliberate. It covers the whole of the animal kingdom, all the palaeontological time, the whole world. What's nice, what's different, is that there are lots of skeletons and skulls in jars without too much taxidermy, because it's more of a teaching collection.

Taxidermy isn't that useful for teaching. It was initially set up to teach the first courses in zoology and comparative anatomy. Robert Grant was one of the leading comparative anatomists, of the 19th century, and the first 10,000 or so objects here are his, so [there is] definitely a comparative anatomy focus across the museum.



### **Which specimen would you say has the most educational value?**

That's a tricky question, because measuring educational value is pretty subjective. Our rarest specimen is a quagga, an extinct species of a not-very-striking zebra that became extinct in 1883. We have one of only seven skeletons in the world and the only one on display in the UK. It's also pretty cool as it was actually missing one of its legs, so we CT scanned the surviving leg, flipped the data and 3D printed a replacement leg. We've also got the only fluid-preserved adult thylacine [an extinct carnivorous marsupial] in the world on display.

### **Do you have a favourite specimen from the museum that you've included in your book?**

I do. My particular interest is the zoology of Australian mammals and their ecology and evolution, and so platypuses are very much my favourite animal. So I have used that as object number one, which is completely out of order from the rest of the book, just because it's my favourite specimen.

### **What do you like about the platypus?**

They are an evolutionary biologist's dream because the platypus often gets inaccurately described as a primitive animal. They have distinctive features inherited from their reptilian ancestors — they famously lay eggs and walk with bent elbows and knees, akin to a crocodile. But on top of their relatively primitive frame they have some of the most bizarre yet advanced characteristics of any mammal.

Did you know they are among the only mammals that can detect electricity? A platypus' bill can detect electrical impulses generated by the muscular movement of their prey underwater, and the male platypus is one of just a few venomous mammals. Evolution has taken this animal, which has been around for approximately 120 million years, and without changing much of its ancient features, added some of the most advanced characteristics of any mammal. They also look pretty weird, huh?

### **How are the samples in the museum preserved?**

The most common three [methods of preservation] are taking the bones out, taxidermy skins and fluid preservation, and to an extent they stay pretty much the same; preparing bones hasn't changed a great deal. The only real thing that has come up in the last few decades is how to speed things up a bit — large animals traditionally just get buried and that still happens today.

People will still bury whales to prepare the whalebones, and there are stories from both University College London and the Natural History Museum that there were whales buried, still buried, in the gardens that people have forgotten about. [After being buried] you can use warm water or wet sand. These days you can use biological washing powder; the enzymes in it will speed up the process by chewing on the biological bits of soft tissue. You can also use live carpet beetles.

One of the biggest threats to museum collections is being eaten by a pest, so these are a problem for museums, but actually they've now been used as helpers by locking them in tanks

with small carcasses, then the beetles will strip the flesh from the bone. In terms of fluid preservation it is something people are learning about because you don't know if it works until maybe decades later. Different fluids come in and out of fashion.

#### How do you preserve a sample in fluid?

There are two stages to preservation. First you have to fix the specimen — this halts the process of decomposition by binding the organic molecules inside each cell. That's commonly done with formalin, which is dilute formaldehyde gas in solution. It's a really nasty carcinogenic [cancer-causing] chemical, so not something you want to be around much. Fixing is done inside the animal, but the second step is preserving, which is basically pickling to maintain [the specimen's] structure in the long term. Formalin was used as a preservative and can still be used, but now we more commonly use industrially methylated spirits.

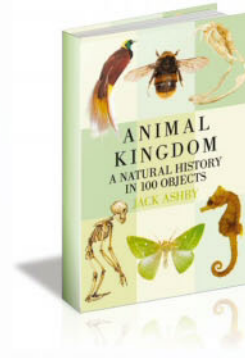
#### Have you ever had a problem with your specimens that have gone rotten or been dropped?

It happens rarely, but if something has been there for a very long time and all of the alcohol has evaporated, the specimens will start to rot. Sometimes what happens — particularly in university museums where a collection has kind of evolved organically from a lot of people's research specimens — people would have been collecting something for their research in the 1950s and stuck it in a bucket waiting for it to be properly preserved. But rather than fixing it they might have just put it in a bath of alcohol, and then we'll open it 70 years later and it's rotten. Rarely do disasters happen, but there are occasional times where fixatives don't work. You'll find the specimen has rotted away and you might be able to salvage a skeleton, but otherwise you'll just have to throw it away.

#### How did you select just 100 specimens from 68,000?

It was difficult. Every object tells thousands of stories. There is some real bias about the animals we hear about on TV, in books and museums. We mostly hear about the big, dramatic animals, but actually most animals are invertebrates. They just don't get a lot of coverage. So the first section is about diversity. It just goes through most of the ways of being an animal, most of the major groupings of animals. I didn't do all of them because quite a lot of them are worms, and there are not a lot of different things to say about the

really small groups of worms. [Throughout the book] I wanted to tell what I found to be the most interesting aspects of natural history. So what are the weirdest stories in terms of natural selection, sexual selection, competition, and adaptation. I really thought about which animals or specimens would really show those big stories, and then to finish with I wanted to get into what makes museums a bit weird. They're



Jack Ashby's  
Animal Kingdom: A  
Natural History in 100  
Objects is available  
now, published by  
The History  
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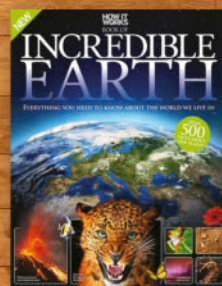
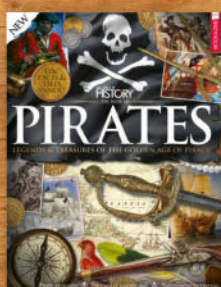
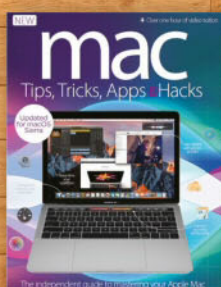
not sterile or natural or even necessarily scientific places, but they're human inventions and they're products of their own history; the biases of human nature and human politics, which affects how people understand animals.

*"A platypus' bill can detect electrical impulses generated by the muscular movement of their prey underwater, and the male is one of just a few venomous mammals"*



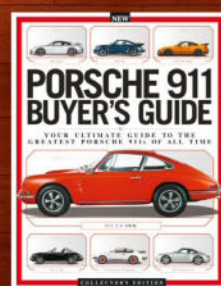
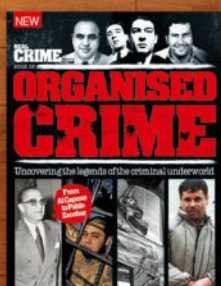
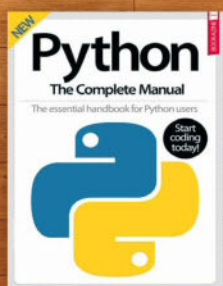
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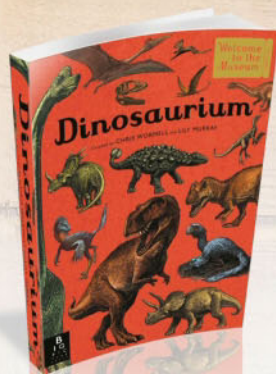
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From gyroscopes to dinosaurs to your very own robot, we've got you covered this festive season



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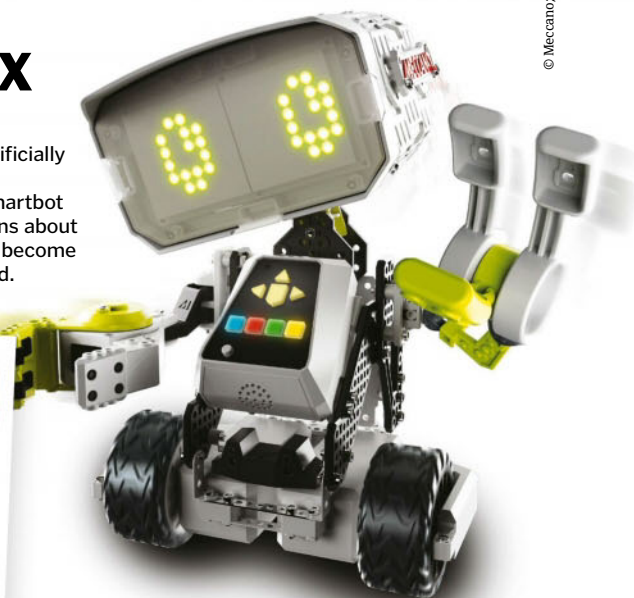
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**DID YOU KNOW?** In the first *Star Wars* film vaseline was applied to the camera to give the illusion of Luke's speeder hovering

# THE SCIENCE

# STAR WARS

How our laws of physics apply in a galaxy far, far away

**T**his holiday season, audiences across the world will be flocking to cinemas to watch *Star Wars: The Last Jedi*, the latest instalment in the hugely popular franchise. But while Rey, Finn and Luke are making their way across the galaxy in a fantastical universe, some more eagle-eyed observers might be wondering if they'll obey the laws of physics when they're battling the forces of the dark side.

*Star Wars* is of course space fantasy, but that doesn't mean you can't throw a bit of science fact in there too. Space travel, laser beams and droids are all things that we're getting better at, and while we haven't quite reached *Star Wars* levels yet, it might not be too long until your very own protocol droid is helping you around the home.

In the *Star Wars* galaxy we often see ships travelling at blistering speeds, covering huge sectors of space in seemingly no time at all. As

far as we know, it isn't possible to break the speed of light, making journeys like those undertaken by the *Millennium Falcon* quite implausible. But we do think it might be possible to at least approach the speed of light. In fact, scientists on Earth are already looking at ways to visit our nearest star — Proxima Centauri — by doing just that. True, we don't have any sort of hyperdrive yet, but who knows, maybe the next breakthrough is just around the corner.

**"Maybe the next breakthrough is just around the corner"**

The vehicles of *Star Wars*, while sometimes far-fetched, also have some real world similarities. The shifting wings of the X-wing look pretty similar

to variable-sweep wings we see on some jets, and we've even made rudimentary speeder bikes too, albeit with propellers rather than anti-gravity devices. And then there is mobile phone technology. You've probably got a smartphone near you right now that is packed with the latest

virtual assistant to help you go about your day. It might not look as impressive as R2-D2, but it sure gives you plenty of help, just like the little robot.

Everyone's favourite, though, is of course the humble lightsaber. While we can't quite create beam swords yet, we're getting better at trapping plasma to use in nuclear fusion reactors. Will our distant descendants find a way to shrink this machinery down to a handheld device? It seems unlikely, but hey, even a Jedi has to start somewhere. So strap in with us as we take a look at how feasible the science and technology of *Star Wars* really is.

## WITH THANKS...

Many thanks to **Dorling Kindersley** and **Disney/Lucasfilm** for giving their permission to use their fantastic illustrations and imagery, taken from the following DK titles:

- *Star Wars: The Force Awakens: Incredible Cross-Sections*
- *Star Wars: The Force Awakens: Visual Dictionary*
- *Star Wars: The Complete Visual Dictionary*

Check out the official *Star Wars* YouTube channel to watch their multi-part series: *Science and Star Wars*.

# REY'S SPEEDER

How close are we to making a vehicle that floats off the ground?

Ah, the hover bike. Long sought after but not so easily attained, many efforts have been made to recreate something like Rey's speeder. In the *Star Wars* universe, Rey's custom speeder uses a technology called repulsorlift to hover over the ground. This anti-gravity technology pushes against the surface of a world in order to generate lift.

Of course, that's pure fiction. But that doesn't mean there aren't other ways to make hover bikes. Using propellers and fans, some inventors have come up with some pretty novel ideas, and maybe one day in the future we'll have something that looks a bit more similar to Rey's speeder.

Seat tractor beams keep Rey in place

Made from various scavenged parts, Rey's speeder requires skill to pilot



Rear stabiliser vane

Exhaust nozzles

Similar to a modern spacecraft, the speeder uses exhaust nozzles to help steer.

Afterburners

Adding more fuel into the jet pipe allows for an additional burst of speed.

## Inside the speeder

How this vehicle holds up in the *Star Wars* (and our own) universe

**Manufacturer** None (custom made)

**Model** Customised repulsorlift vehicle

**Class** Hybrid speeder/swoop

**Length** 3.7 metres

**Crew** 1 pilot

Electric security

The chassis of the speeder is electrified to keep thieves away.

Repulsorlift

This fictional anti-gravity device generates lift for the vehicle to hover.

Ground clearance

The Aero-X hovers 3m off the ground using rotating carbon-fibre fans, and can reach speeds of 72kph.

## In reality

One of the closest vehicles we have to a speeder is the Aero-X low-altitude hoverbike

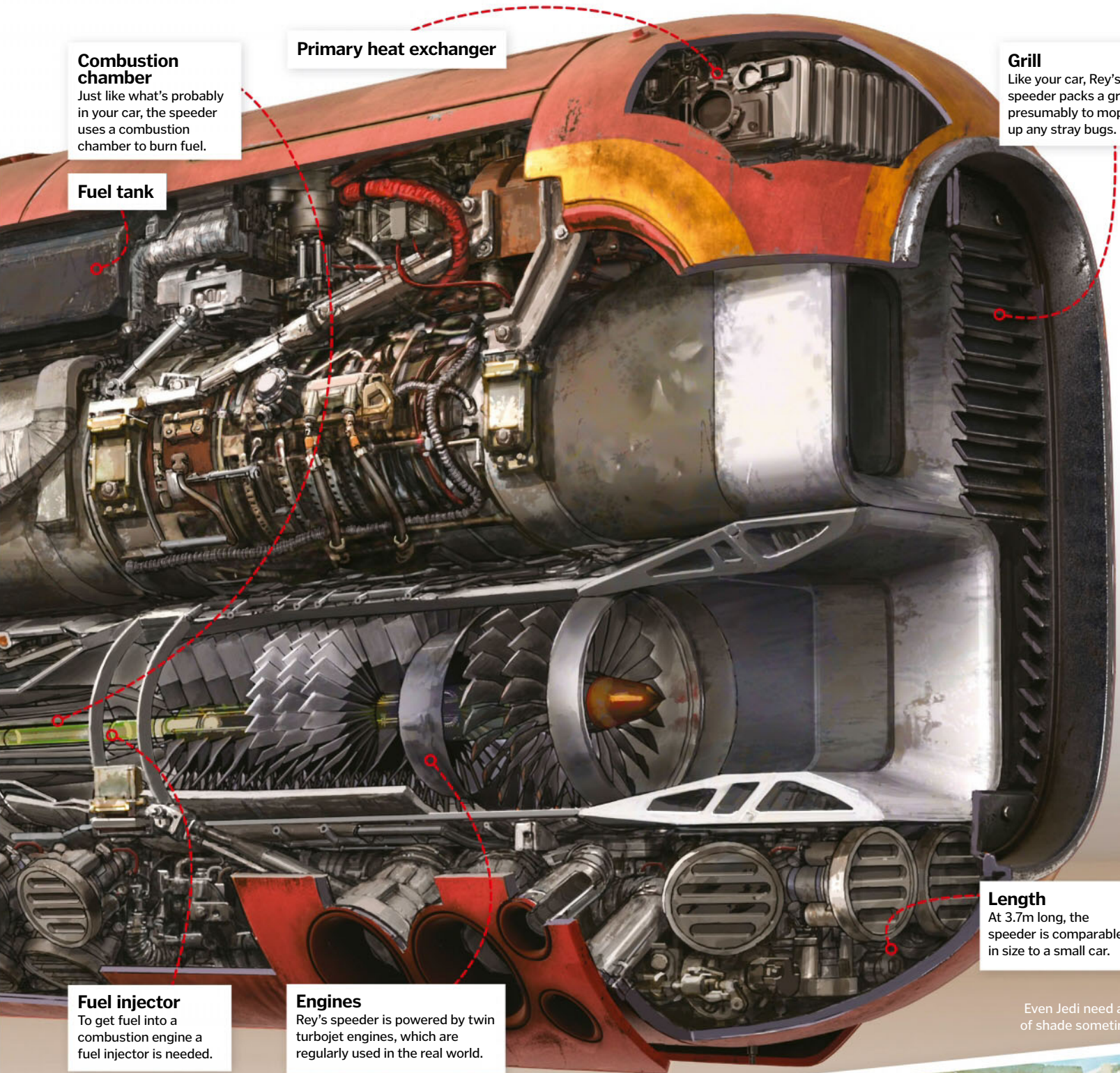


Vertical lift

The vehicle takes off vertically with no need for a runway, and can run on standard petrol for up to 75 minutes.

"Rey's custom speeder uses a technology called repulsorlift"

**DID YOU KNOW?** That incredibly fast speeder bike chase in Return of the Jedi was actually filmed at walking pace in a forest



**Combustion chamber**

Just like what's probably in your car, the speeder uses a combustion chamber to burn fuel.

**Fuel tank**

**Primary heat exchanger**

**Grill**

Like your car, Rey's speeder packs a grill, presumably to mop up any stray bugs.

**Fuel injector**

To get fuel into a combustion engine a fuel injector is needed.

**Engines**

Rey's speeder is powered by twin turbojet engines, which are regularly used in the real world.

**Length**

At 3.7m long, the speeder is comparable in size to a small car.

Even Jedi need a bit of shade sometimes



Speeder bikes are common in the *Star Wars* galaxy





The hum of old film projectors and TV interference makes the famous sound of a lightsaber

# THE WEAPONS

Lightsabers, blasters and planet-killing lasers... What more could you want?

Ask someone to tell you anything about *Star Wars*, and lightsabers will probably be near top of the list. Not far behind will be the huge Death Star, and we reckon blasters might be in with a shout too. But is there any real science behind them?

Creating a laser that could destroy a planet, be it on a Death Star or a Starkiller Base, might be a bit tricky. You'd need about as much energy as a supernova produces. Blasters, on the other hand, might be a bit more manageable. The US Navy has developed a ship-based laser weapon

system that can destroy targets, although we're a long way off handheld laser cannons.

As for lightsabers, well, they are the perennial holy grail of science-fiction fantasies. Perhaps some sort of plasma in the real world could do the job.

## Lightsabers and blasters

How some of the most fearsome weapons in the galaxy work

### Blade emitter

This is where the pure energy blade of the lightsaber comes from.

### Kyber crystal

Inside a lightsaber you'll find a kyber crystal. Their unique properties are sadly purely fiction.

### Primary crystal mount

### Colours

A chlorine plasma could provide a green hue, while a helium plasma would turn red.

### Magnetic field

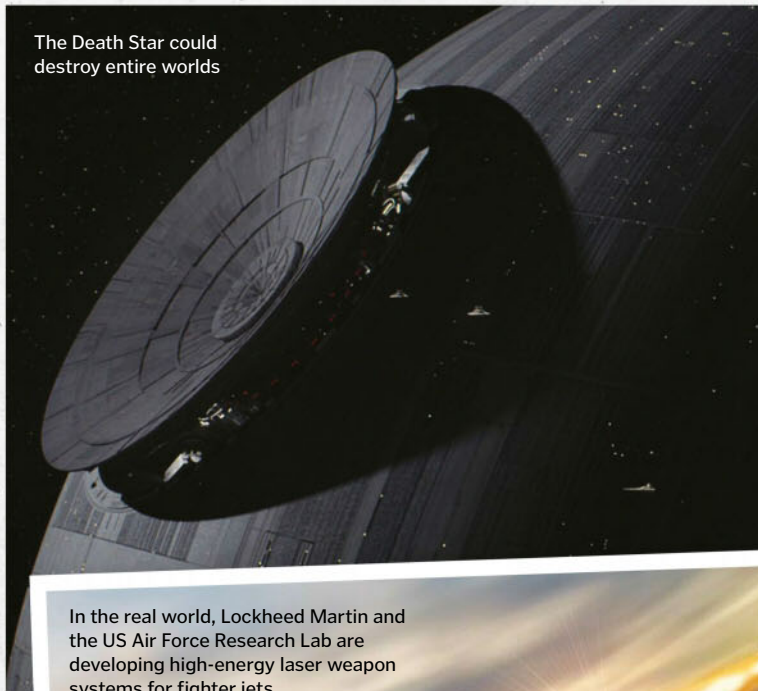
Some sort of magnetic or electric field could help contain the beam of the lightsaber in the real world.

### Blade energy channel

### Focusing crystals

### Energy gate

**DID YOU KNOW?** The earliest drafts of the *Star Wars* script referred to lightsabers as 'lazerswords'. Thankfully, it didn't stick

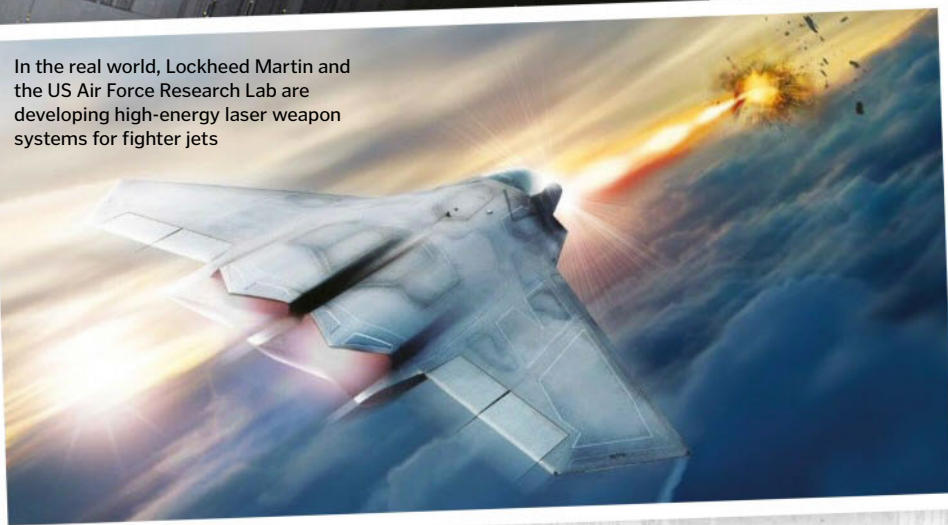


The Death Star could destroy entire worlds



© Alamy/Getty; Air Force Research Lab

The Death Star isn't too scary in real life



In the real world, Lockheed Martin and the US Air Force Research Lab are developing high-energy laser weapon systems for fighter jets

"Creating a laser that could destroy a planet might be a bit tricky"

Hitting a guy-wire with a hammer generates the sound of a laser blaster firing

### Power cells

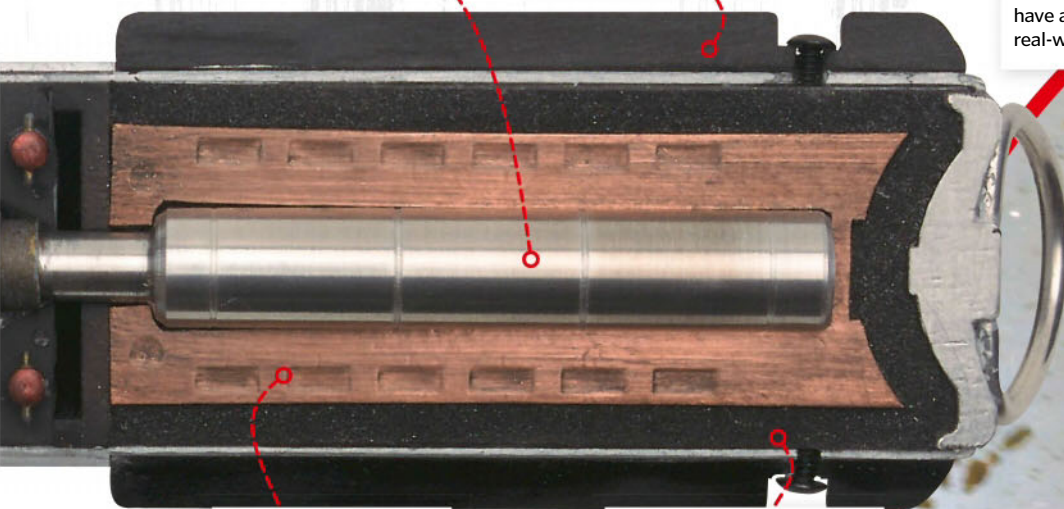
The diatium power cell uses fictional trumponium gas to form the plasma rod in the *Star Wars* universe.

### Power

To power a lightsaber you'll need the same energy consumption as 14,000 average houses.

### Shape

Blasters in *Star Wars* have a similar shape to real-world weaponry.



Power vortex ring

Inert power insulator



### Plasma energy

Fire bolts of plasma energy — not lasers — at their targets, something we can't do yet.

# THE MILLENNIUM FALCON

Could this iconic ship really have graced the skies of the *Star Wars* universe?

Perhaps there is no spaceship as memorable as the *Millennium Falcon* in any film or TV show. Once merely a freighter, it proved its worth by helping to destroy two Death Stars, and it could even make mincemeat of the Kessel Run.

Although many of the technologies employed were a bit far-fetched, some are grounded in reality. Its impulse engines for one were powered by nuclear fusion, something that we're just getting to grips with in the real world. And while this ship could travel faster than the speed of light, we do know it's theoretically possible for a spaceship to at least get near to light speed.

## Inside the Falcon

How this ship may have transported Han Solo across the galaxy

**Manufacturer**  
Corellian Engineering Corporation

**Model**  
Corellian YT-1300f light freighter (modified)

**Class**  
Transport

**Length**  
34.75 metres

**Crew**  
2 (minimum)

The ship is powered by fictional exotic particles called hypermatter, which you won't find in any textbooks. But we do know of plenty of other exotic matter. Maybe something out there might power our own *Millennium Falcon* one day.

### Power core

The *Millennium Falcon* was powered by hypermatter, an exotic form of particles that you won't find anywhere in our real universe.

### Water recycling

Just like on the ISS, the *Millennium Falcon* recycles its water, providing its crew with drinking water.

### Hyperdrive

Using fictional hypermatter, this drive enabled the ship to go faster than light, which is something that's just not possible in our current understanding of physics.

### Fuel

The ship's below-light-speed engines were powered by radioactive liquid metal — something we probably wouldn't recommend launching into orbit.

### Sublight engines

The nuclear fuel was ignited to start a fusion reaction to provide thrust. Fusion rocket design is a purely hypothetical idea, however.

### Escape pods

On the ISS, astronauts use Soyuz capsules as emergency pods — not too far removed from what you see here.

### Hyperdrive vent

This ejects tachyons into space, hypothetical particles that can travel faster than light. However, we've never found any.

**DID YOU KNOW?** The Millennium Falcon has a class 0.5 hyperdrive, capable of taking the ship "0.5 beyond light speed"

### Weapons

While the laser cannons might be a bit far-fetched, it's rumoured the Soviet Union once tested a cannon in space.

### Main hold

Passengers can 'relax' in the main hold during flight and even sit down to a game of dejarik (holographic chess).

### Anti-gravity

The acceleration compensator apparently keeps the crew grounded in the ship. Anti-gravity systems like this, however, do not exist.

### Cockpit

Witness to many tense moments, most of the *Falcon* is controlled from here, including the deflector shield.

### Airlock

Airlocks are something we use regularly in spaceflight, and this design looks similar to what you'd see on the ISS.

The International Space Station's Quest Joint Airlock can be depressurised to prepare astronauts for spacewalks, and pressurised again when they return

# DROIDS

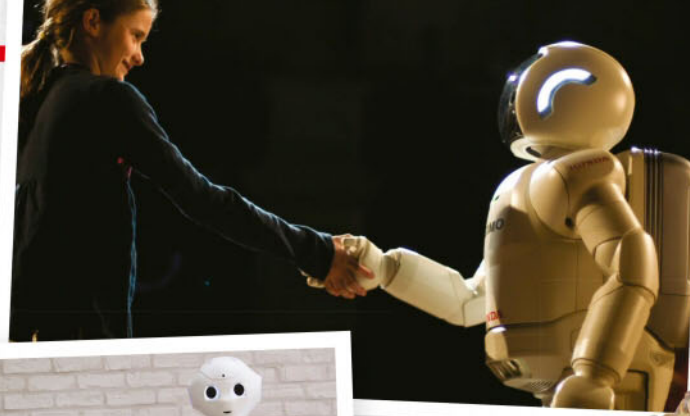
## These might just be the droids you're looking for

The droids of *Star Wars* can be cute, helpful and even menacing at times. All of them seem to have vastly impressive artificial intelligence (AI), but maybe we're not too far off.

Most of our smartphones now have robotic assistants that help us with our day, sometimes even increasing their knowledge by teaching themselves. And our physical robots are getting better too. Like C-3PO, we've designed plenty of awesome robots that mimic the actions of a human. And robotic security droids used by some businesses certainly elicit thoughts of BB-8 and R2-D2. If you're looking for a robot pal, you don't necessarily need to travel to a galaxy far, far away.



Advancements in robotics and artificial intelligence have already brought us closer to real-life droid companions



### Language

While Google Translate can't match C-3PO's 6 million forms of communication, it's certainly a step in the right direction.

## Mind machines

How these robots help our heroes in times of danger

### Magnetic casters

BB-8 uses magnetic casters to keep its head attached to the top of its rolling body.

### Photoreceptor

Like a camera, the eye of BB-8 can see its surroundings and work out what it's looking at.

### Body

C-3PO's metal exterior wouldn't look too out of place on a robot on Earth.

### Legs

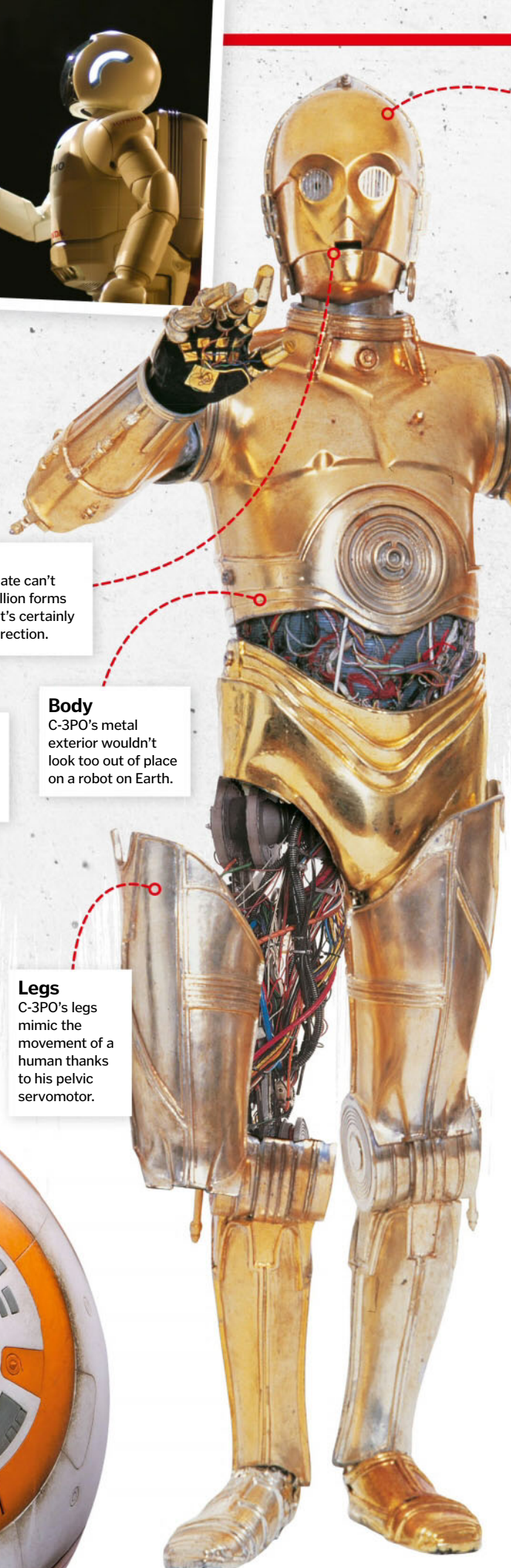
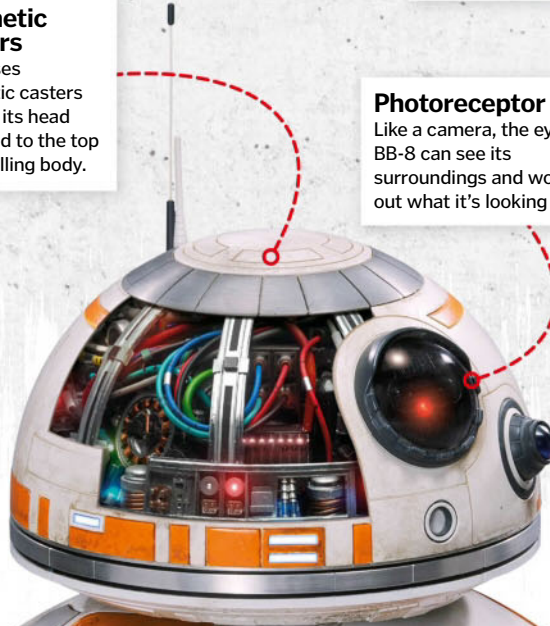
C-3PO's legs mimic the movement of a human thanks to his pelvic servomotor.

### Rotation

The head rotation motor is attached to a central mast, which is in turn connected to a magnetic base with wheels.

### Movement

BB-8's rolling body allows it to traverse tricky terrain that other robots cannot manage.



**DID YOU KNOW?** It might have looked autonomous, but R2-D2 was actually controlled by actor Kenny Baker

### Logic function computer

C-3PO's brain helps him operate as a protocol droid, and his memory can be wiped when necessary.

### Imaging system

R2-D2's extendible imaging system can capture images of his surroundings.

*"Most of our smartphones now have robotic assistants"*

### Holographic projector

We see plenty of holograms in the real world, though they might not carry such important messages as R2-D2.

### Arm

A simple robotic arm helps R2-D2 tap into computer interfaces.

### Feet

R2-D2's feet come with tiny rocket thrusters to get him out of tight spots.

## Real-life droids

The highly advanced robots currently used for specialised tasks



### AEODRS - Bomb disposal robot

These life-saving droids are used by specialist teams to help disarm or remove bombs



### DA VINCI SURGICAL SYSTEM - Robotic surgical assistant

This medical bot helps surgeons perform minimally-invasive and ultra-precise operations



### KUKA KR 1000 TITAN - Robotic arm

Devices like the Titan are commonly used to help build vehicles, providing power and accuracy



### NASA'S CURIOSITY MARS ROVER - Robotic explorer

Some droids have the job of scouting out other worlds for future human exploration

**WIN!**  
YOUR OWN  
**BB-9E**  
SPHERO  
DROID

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# POE'S X-WING

## How this spaceship might have helped the Alliance in their battle against the First Order

The X-wing once helped destroy the Death Star, but now in *The Last Jedi* it's got a new lease of life in the fight against the First Order. And thankfully, there's plenty of technology here that we also see in the real world.

The wings of the X-wing, for example, can shift between their parallel cruise mode and the iconic X-shaped attack mode. In the real world, variable-sweep wings mimic this action, as seen on jets like the F-14 Tomcat. Deflector shields

aren't too far beyond the realms of reality either, as we're learning to manipulate magnetic fields like never before. You might not be jumping to hyperspace any time soon, but the science behind the X-wing has plenty of credibility.

### Hyperdrive

While approaching the speed of light works in theory, we don't know how to do it in practice yet.

### AI assistant

Most planes make use of an autopilot feature just like little BB-8 here.

### Thrusters

A fictional fusial thrust engine helps the X-wing travel at sublight speeds.

### Laser generator

### Landing gear

## Inside the X-wing

How this ship tears its way through the galaxy

### Manufacturer

Incom-FreiTek

### Model

T-70 X-wing

### Class

Starfighter

### Length

12.5 metres

### Crew

1 pilot plus 1 astromech droid

### Deflector shield

These energy fields can, like a magnetic field, deflect incoming beams.

### Laser cannon charge cells

### Proton torpedoes

We might not have any in space yet, but ships on Earth regularly use torpedoes in warfare.

### Suppressor

Like the recoil of a gun, the magnetic flashback suppressor prevents feedback damage from the laser cannon.

### Laser cannon

The KX9 laser cannon on the X-wing can rip through others ships, but we can't recreate this yet.

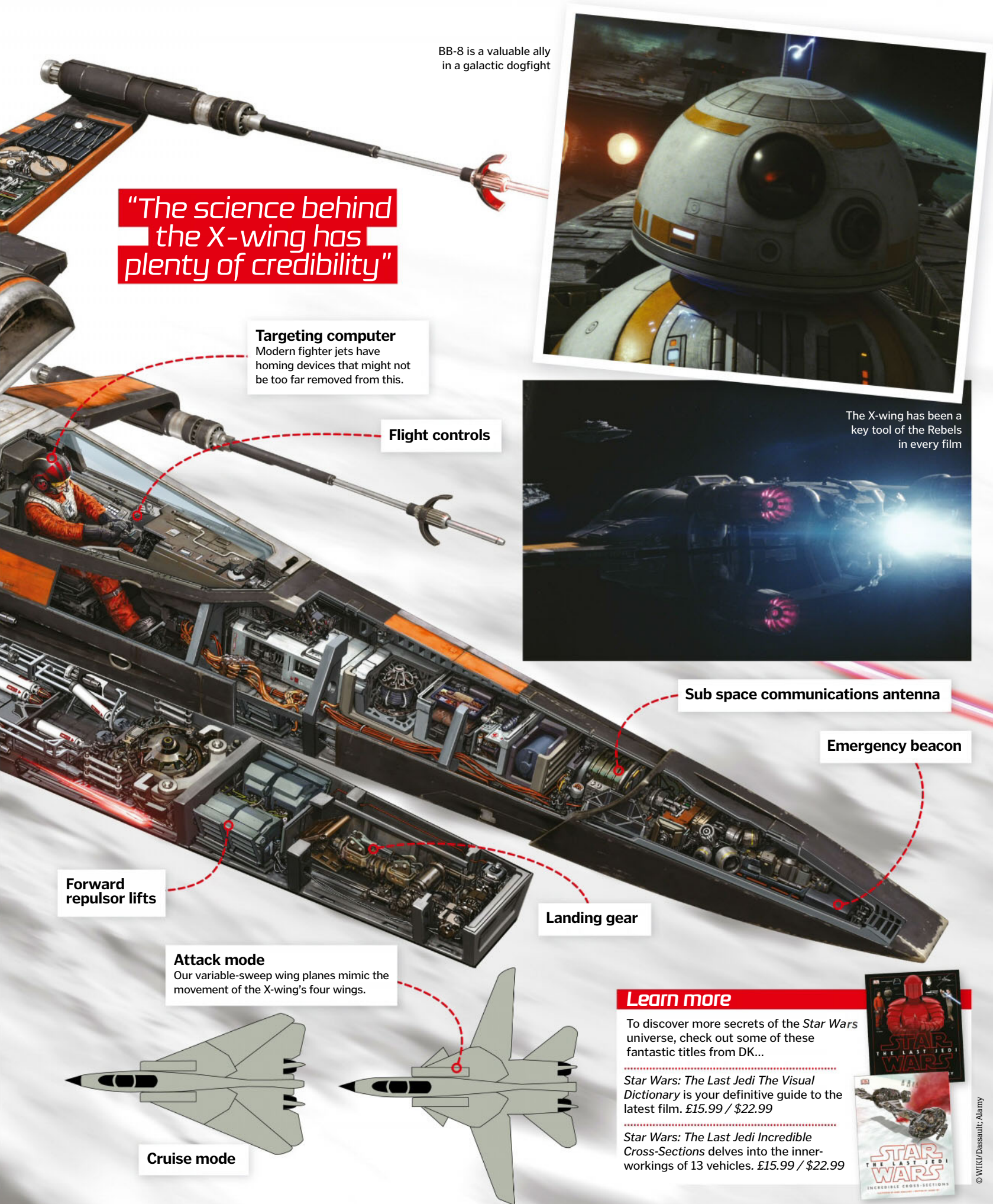
The X-wing made a reappearance in *The Force Awakens*



In our own universe, variable-sweep wing aircraft can modify their wing positions to suit flight at different speeds



**DID YOU KNOW?** World War Two dogfighting footage was used in initial cuts of *Star Wars* to keep the production on schedule



BB-8 is a valuable ally in a galactic dogfight

**"The science behind the X-wing has plenty of credibility"**

**Targeting computer**

Modern fighter jets have homing devices that might not be too far removed from this.

**Flight controls**

The X-wing has been a key tool of the Rebels in every film

**Sub space communications antenna**

**Emergency beacon**

**Forward repulsor lifts**

**Attack mode**

Our variable-sweep wing planes mimic the movement of the X-wing's four wings.

**Landing gear**

**Cruise mode**

**Learn more**

To discover more secrets of the *Star Wars* universe, check out some of these fantastic titles from DK...

*Star Wars: The Last Jedi The Visual Dictionary* is your definitive guide to the latest film. £15.99 / \$22.99

*Star Wars: The Last Jedi Incredible Cross-Sections* delves into the inner-workings of 13 vehicles. £15.99 / \$22.99



## Star Wars: Destiny

*The light against the dark in a strategic dice and card game*

■ Publisher: Fantasy Flight Games ■ Price: £29.99 / \$29.95 ■ Number of players: 2 ■ Ages: 10+ ■ Typical game time: 30–40 mins

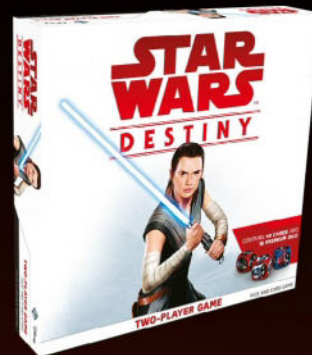
In dice and card game *Star Wars: Destiny*, two players face off against each other, one representing the light side, one the dark side, each striving to eliminate the opponent's characters first.

The rules are relatively straightforward but have a strong deep-strategy element to them as well. The base version contains two characters on each side: Rey and Poe facing off against Kylo Ren and Captain Phasma. Along with your characters you have a deck of cards containing support, events and upgrades. You have shields

to apply, limited resources to use and all-important damage to inflict. The upgrades you apply to your characters can be massively helpful as they make them both more powerful and harder to eliminate, so using them well and early is paramount.

It's important to use a balanced strategy of attack and defence, as we found that going on all-out attack left us vulnerable to surprise events from the opponent's card deck, and once you lose a character (especially when playing only two characters per team) the going gets

extremely tough. However, we also found being too cagey led to problems when it came to finally trying to damage the enemy. Finding the right order of your actions from the start is vital, as each turn — especially early on — has a limited number of actions. *Star Wars: Destiny* is fast-paced, and once you get the hang of the rules and basic strategy it has great replay value.



### The die is cast

Claiming supremacy in battle requires quick thinking, a level head and ruthlessness

#### The field of battle

Home advantage counts when it comes to the battlefield. You can claim control of it, which gives you the upper hand.

#### The star cast

These are your most important assets — keep all your characters alive for as long as possible.

#### Upgrading

Similar to how a bulletproof vest can stop a bullet, the right upgrade can make your character much harder to down.

#### Inflicting pain

Damage counts — literally. When attacking, focusing on one character first in order to eliminate them can lead to victory.

#### Limited resources

Just like you can't run a car on an empty tank or battery, you can't do much without resources. Make sure to keep stocked up.

#### Eventful battle

A surprise event can change everything, so having an Event card in your hand is a wise move.



# TIME TO STEP OFF THAT TREADMILL

With so many demands from work, home and family, there never seem to be enough hours in the day for you. Why not press pause once in a while, curl up with your favourite magazine and put a little oasis of 'you' in your day.



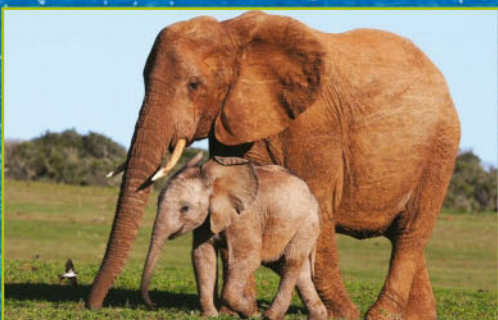
**PRESS PAUSE**  
ENJOY A MAGAZINE MOMENT

To find out more about Press Pause, visit;  
**[pauseyourday.co.uk](http://pauseyourday.co.uk)**



# WHAT MAKES A MAMMAL?

Author Liam Drew explains what sets us apart from the other classes of the animal kingdom



## MEET THE EXPERT



Liam Drew is a writer specialising in biology and medicine. He previously worked as a neuroscientist at UCL and Columbia University in the US.

It was while my daughter was being breastfed — which happened right after I'd spent months occasionally getting an ultrasound peep at her growing inside a womb — that I became interested in my being a mammal.

I'd known that I was a mammal for as long as I could remember, and I had some basic grasp that it meant I'd once subsisted solely on milk and that I had hair and was warm-blooded. I also knew that humans were placental mammals, not pouched marsupials or egg-laying mammals like the platypus and its closest cousins, and so we develop in wombs, nourished there by placentas. But beyond these basic facts I wasn't at all sure what defined a mammal or how this type of animal had evolved. Suddenly, consumed with an interest in the elemental aspects of my biology, I decided to find out more about what makes me like a fox, hedgehog and giraffe, and unlike an anaconda, turtle or pigeon.

My approach to this question was initially pretty 18th century. Back then people defined groups of plants and animals not by their being descended from shared ancestors but according to which unique features they shared. Shared reproductive biology and a need to breathe air made Carl Linnaeus declare in 1758 that whales and dolphins weren't fish but members of a natural group with furry, warm-blooded land animals.

To name this new group he'd created, Linnaeus chose — with no explanation — the

Marsupial mothers have relatively short pregnancies but keep their vulnerable offspring safe in their pouches



## "Mammals' closest living relatives are reptiles"

mammary gland as the defining shared feature they'd be named after, thereby coining the term 'mammalia', which we translate as mammals. But a century after mammals were first grouped together, Charles Darwin published his great book *On the Origin of Species by Means of Natural Selection* and biologists came to widely accept that animals evolved.

According to Darwin, mammals were a group of animals more closely related to one another than to any other type of creature, and the features they share are owed to them having been inherited from a common ancestor. To explain where these traits came from one had to first explain what the advantages were of having them conferred on their possessors and also how

they had come to exist from an ancestor that had not had them.

How, for instance, had a mammary gland evolved from a milk-less ancestral state?

Mammals' closest living relatives are reptiles, who are members of a much larger class of

animals called Sauropsida, which also includes birds. And we know now that the mammalian and reptilian lineages diverged about 310 million years ago. Their last shared ancestor looked decidedly more reptilian than mammalian. And from that cold-blooded, milk-less and hairless (not to mention small-brained, sprawling-limbed and primitively toothed) starting point, the succession of pre-mammalian ancestors who morphed into true mammals evolved all the traits that we associate with mammals today.

The first recognisably mammalian creatures lived about 210 million years ago. Much of what we know about the evolution of mammals therefore comes from fossil records. But this information is also today combined with conclusions drawn from comparing the bodies — and DNA — of all the various 5,500 living mammal species.

## Eggs, pouches and placentas

Living mammals are divided into egg-laying monotremes, marsupials (which are named for their pouches) and placental mammals. Eggs of platypuses and their kin differ from reptile and bird eggs in growing in the uterus by absorbing maternally secreted nutrients, while marsupials have very short pregnancies that briefly involve placentas. These mammals birth foetal-like newborns that must ascend their mothers' abdomens to latch onto a nipple, which they remain constantly attached to for weeks or months. Milk powers most of the marsupial's development, whereas the young of placental mammals gather much more of their mothers' investments in them via the placenta. This organ breathes, eats, and performs many other vital functions for the young placental mammal, mediating a dynamic relationship between mother and offspring.

© Getty/Thinkstock



## MILK

Lactation, that definitional feature of mammals, was central to one of the most extensive attacks on Darwin's theory of natural selection after it was first published. A scientist named St George Mivart could not accept that something as complex as an infant obtaining nutrition from a specialised gland on its mother's torso could have gradually evolved via many, many small, advantageous changes to a once milk-less body.

Darwin replied by saying that he thought that if mammalian ancestry had once lapped at sweaty secretions from inside a pouch, say, then any change to that sweat-like substance that made it more nutritious would have been selected for, and the young who more eagerly sought it out would live better too.

Today, it's roundly agreed that mammary glands evolved from sweat glands. However, it's generally thought that milk didn't evolve from something that was a food source. Instead, milk's hypothesised to have arisen from modifying a secretion that was released from maternal mammals' abdomens to keep their eggs healthier. For milk evolved long before mammals developed wombs and live birth.

There is, however, disagreement over how exactly this solution aided egg health. One theory is that because mammals never evolved watertight egg shells (like the calcified ones of birds) their eggs were prone to water loss, and this would have become an increasing problem as mammals' ancestors became increasingly warm-blooded. Therefore, it's proposed it was advantageous for a mother to essentially sweat onto her eggs to keep them hydrated.

The other main theory also views an increase in body — and thereby egg — temperature as problematic. But in this scenario the problem with the surge in thermal energy was that it fuelled the growth of parasitic bugs. Fascinatingly, if you examine the gene sequences of the major nutritious components of milk today, many bear striking resemblances to molecules used by the innate immune system to attack microbes. It's said, therefore, that milk actually evolved from a solution that was first a sort of egg disinfectant.

In both cases, the transition to milk was driven by hatchlings benefitting from consuming the solution that had protected them inside their eggs and it then being selected to become an ever-better food source.

## HAIR AND WARM BLOOD

Hair is also a structure for which it's hard to imagine what intermediate stages in its evolution would have been good for. A full fur coat is a great source of insulation, but what use would a few straggly or short hairs have been?

Again, it's thought that hair and its precursors changed function through its evolution. One theory suggests that hairs originally developed as sensory structures akin to whiskers. It's much easier to imagine that a few small, lever-like protrusions would have had advantages for tactile sensing as their possessors sniffed about their environments and that this sense improved with longer protrusions. Then, the theory goes, mutations would have multiplied the number of whiskers until enough were present to insulate an animal.

Another idea is that hairs were originally 'wicks' for getting a sweat-like substance out of glands and onto the skin. Today mammalian skin is covered in glands and all their hairs are lubricated by an oily substance produced at the bases of these glands. Originally this substance may have helped to waterproof mammal ancestors' skin, and to aid its release the glands that made it may have evolved little stick-like protrusions along which the substance travelled to reach the skin. Here, pre-hairs would have covered the body from the get-go but only assumed an insulating function once they were long enough.

Although hair is a truly distinctive feature of mammals, the real biological story is the fact that mammals are warm-blooded. Or to use the technical term, mammals are endothermic, producing their own (endo) heat (therm), as are birds, but to ignore warm-blood because birds also independently evolved it would be to omit consideration of a central element of mammalian biology.

The challenge of explaining endothermy is to say how its advantages outweigh its considerable costs — somehow constantly maintaining a high body temperature must offset a massive hike in energy budget. Mammals eat about ten times the amount an equivalently sized reptile does.

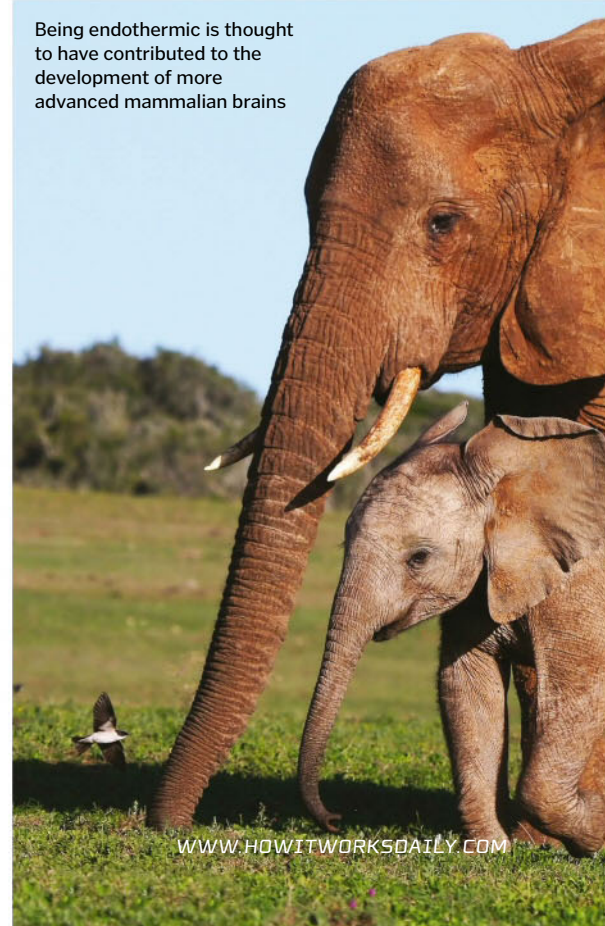
Theories include how being warm-blooded allowed mammals to be nocturnal, operating in the cold of the night when the dinosaurs ruled the world by day; that being warm-blooded evolved naturally as mammals became smaller in those dinosaur days; that endothermy was a by-product of becoming able to maintain higher levels of aerobic performance for longer stretches; and that sustained higher temperatures may have made young mammals develop faster or met the demands of feeding youngsters. Mammals, as well as birds — but not most fish and reptiles — are dedicated parents.

Whatever the exact reasons for their having warm blood, the adaptations of mammals to gather enough food and oxygen to fuel the high metabolic rate that sustains endothermy account for many uniquely mammalian traits.

Despite living in the oceans marine mammals like whales give birth to live young and produce milk



Being endothermic is thought to have contributed to the development of more advanced mammalian brains



## Back to the water

The last shared ancestor of mammals and reptiles was a land animal that was still relatively new to this terrain. Consequently, many characteristic features of mammals are adaptations to terrestrial conditions. Yet numerous lineages of mammals have, to varying degrees, returned to the water.

Otters, polar bears and water voles, for example, are all excellent swimmers, but walruses, sea lions and

seals are even better. But only two mammalian groups are fully aquatic: the Sirenians (including manatees and dugongs) and the Cetaceans (including dolphins and whales). The former group, known as sea cows, are mostly vegetarians who live in warm waters, whereas whales and dolphins span the globe. Like seals, they are kept warm by their fur or blubber and either hunt prey or filter feed.



*"One theory proposes that being warm-blooded allowed mammals to be nocturnal, operating in the cold of the night when the dinosaurs ruled the world by day"*

Mammal species are a wide range of shapes and sizes, but we all evolved from a single common ancestor



For example, only mammals have a muscular sheet (the diaphragm) at the base of their chest cavities. The diaphragm expands that cavity further to allow the mammal to breathe more powerfully. Another key development came when mammals' ancestors stopped laterally bending their torsos as they ran — picture a lizard running, swinging its body and legs side to side. Lateral movements alternately compress the left lung then the right, but moving with a straight body allows mammals to breathe while they run.

Mammals can also breathe while they eat too. Other land vertebrates don't have separate nasal cavities and mouths, but mammals have what's called a secondary palate. It's essentially a bony roof to their mouths that allows air to flow in and out through their noses while they eat, so they only need to stop breathing when they swallow.

This is particularly useful given the amount of time food spends in a mammal's mouth. Long before mammals existed, teeth evolved for food capture and jaws for biting. While mammals' teeth and jaws still do both, their cheek teeth have evolved to grind food by going up and down. Chewing breaks up food while infusing it with saliva's digestive enzymes, a layering that kick-starts digestion, helping to liberate nutrients quicker.

During the mammalian overhaul of the mouth a unique jaw joint also evolved; a joint located between the lower jaw and the cranium that is widely considered the key marker for the emergence of mammals in the fossil record. This joint didn't only change jaw function, however; it also freed two bones that had previously been part of the lower jaw. After getting progressively

smaller throughout evolution, the bones finally left the jaw to begin a remarkable second career as part of the mammalian middle ear.

When sound waves make mammalian eardrums vibrate they trigger a series of vibrations through a chain of three bones. The outer two are the former jawbones and the inner one — which taps against the inner ear — is a former cranial bone. This elegant mechanism amplifies sound waves very efficiently to give most mammals excellent hearing.

The inner ear converts vibrations into electrical signals that are sent to the brain, an organ that in mammals is very large and that is also covered in a uniquely mammalian type of brain tissue. The large size of the mammalian brain is closely linked to endothermy (birds also have very large brains for their size) as neural computations require a lot of energy. Some have even suggested higher intelligence was a driving force behind the evolution of warm blood.

The unique tissue is the six-layered cerebral cortex that is the outermost coating of the brain — the crumpled and folded structure covering a human brain. Many people believe this type of tissue evolved entirely anew in mammals due to a novel way of making brains, but another theory has it that it was instead simply a new way of arranging neural circuits that existed in the ancestors of reptiles and mammals.

Whoever is right, the ways in which information is processed by this cortex are key to

the way mammals think, making them generally smart, and some of them very smart.

So, what we have when we look at a mammal overall is a warm-blooded animal that is finely honed to acquire all the energy it needs to feed its high-energy lifestyle, including sharp senses and high intelligence. Despite its high fuel bill, the mammal way of life is both a highly adaptable and very self-sufficient way of being.

That said, to reach that mammalian level of self-sufficiency requires a great deal of parenting. Mammalian mothers (and occasionally fathers) play an instrumental role in shepherding their offspring through their delicate early stages, from the moment they're conceived through to when they're weaned.

The marvel that is mammalian biology has allowed an incredible range of different mammals to live in all of the world's terrains, from Arctic foxes and polar bears through to badgers and deer, wildebeests and cheetahs to camels and desert shrews. Whales swim, horses gallop, bats fly, kangaroos leap and monkeys climb. And one species can look at all its cousins and think how very wonderful they are.

## Learn more

Discover the full story of our mammalian history in Liam's book, *I, Mammal*, which is out now, published by Bloomsbury Sigma.



Parenting plays an important role in mammalian development



Bats have webbed forelimbs that form wings, and they are the only mammals capable of sustained flight



## Drink your milk

Milk provides young mammals with a foodstuff they don't need to chew, forage or hunt for, detoxify, or digest much. This infant diet enables mammals to grow very quickly toward reproductive age. And although milk is costly for a mother to make, she can gather food at one time of year, store energy as fat and then dispense milk when her young need it. Such maternal storage also means if food is in short supply at any point the young will not suffer.

Milk also helped mammals to evolve specialised teeth. Most young mammals have milk teeth then grow a set of adult teeth in a mature-sized jaw. This enables the teeth to match up perfectly top and bottom to make them more efficient.

*"To reach the mammalian level of self-sufficiency requires a great deal of parenting"*

Regardless of their size, almost all mammals have seven vertebrae in their necks



A mother's milk provides all the nutrients her young will need in early life

A tiger's striped fur provides camouflage, warmth and protection



# Tornado Alley

Discover the region of the US tormented by tornadoes

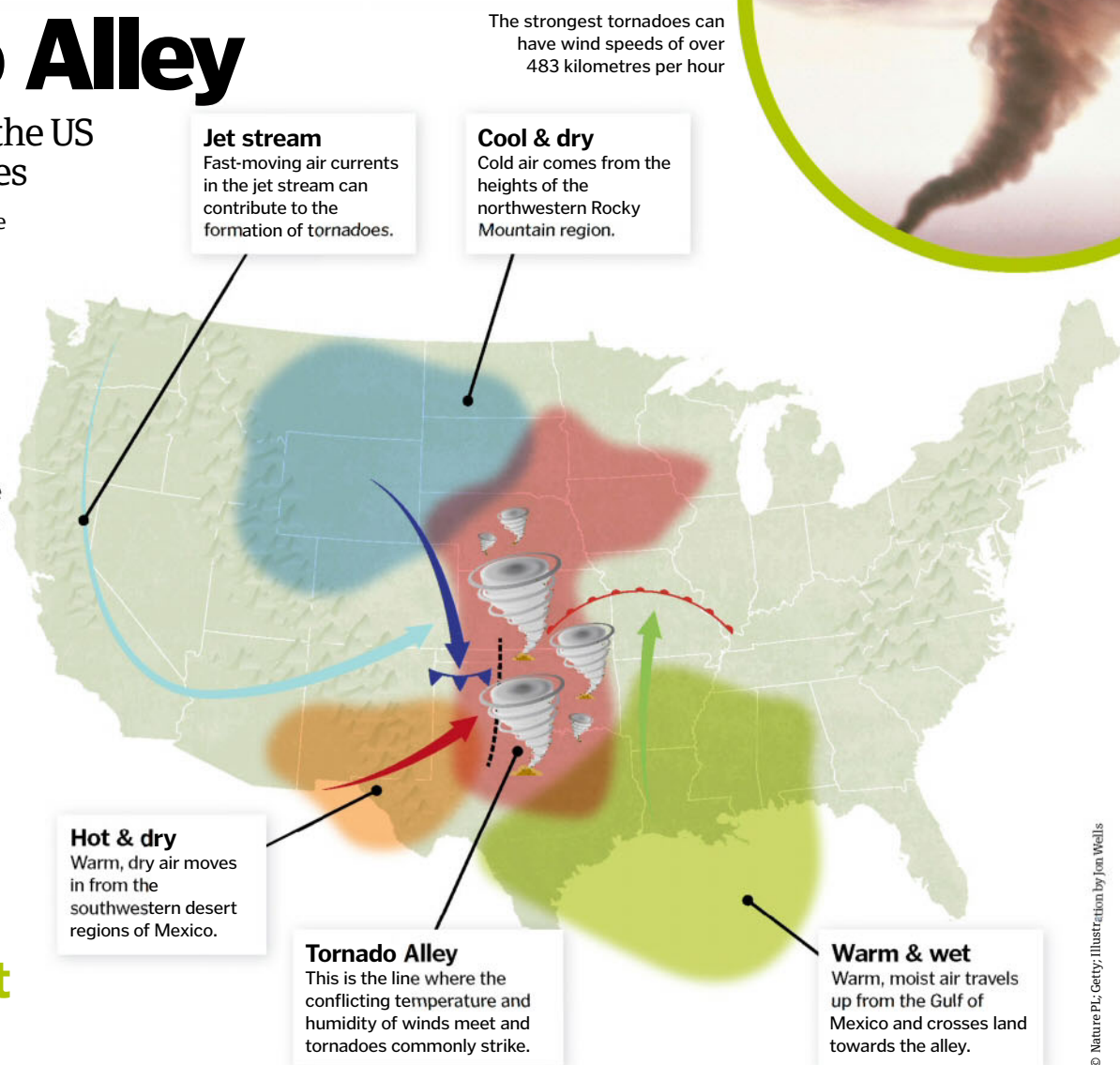
**T**ornadoes are an immense force of nature; they have the power to uproot trees, remove the roofs of houses and throw cars hundreds of metres into the air.

Although tornadoes come in many shapes and sizes, scientists believe they begin as the circling air within a thunderstorm known as a mesocyclone. Certain conditions have been observed to promote a tornado's formation, including contrasting temperatures and humidity. One region of America offers such perfect conditions that it's become a hot spot.

Along the Great Plains a stretch of land crossing states such as Kansas and Oklahoma forms Tornado Alley. This is where weather fronts of different temperatures can converge. Warm, humid winds from the Gulf of Mexico, for example, can crash with the cool dry air rolling in from the Rocky Mountains in the west.

## Weather report

What conditions make Tornado Alley so prone to these storms?



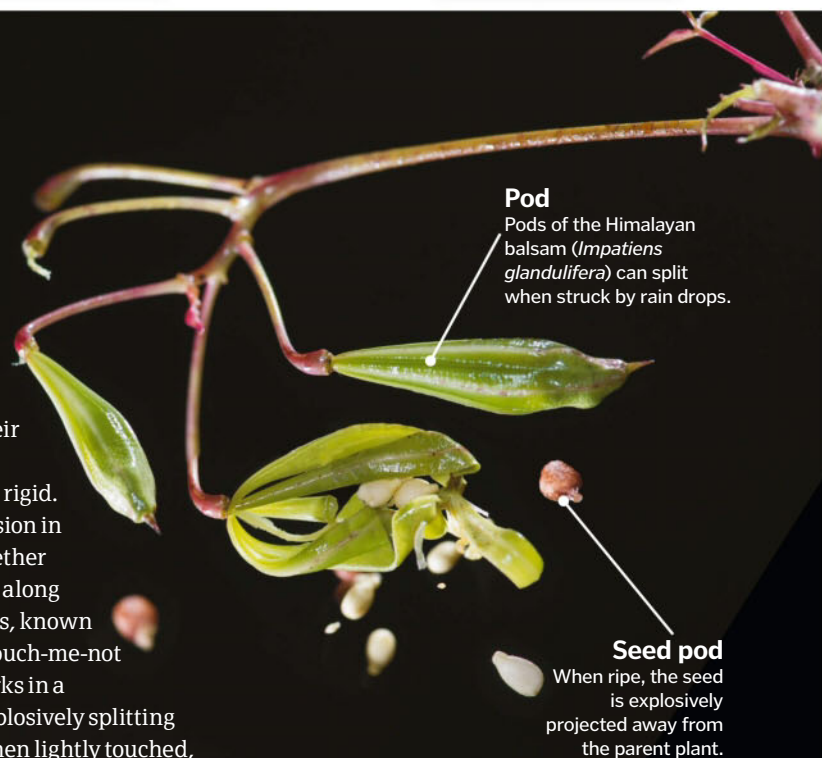
# Exploding seed pods

Discover how some plants can shoot their seeds from bursting pods

**K**nown as ballistic dispersal, the seeds of some plant species are fired from nursery pods to optimise the chances of spreading. This type of dispersal differs in execution for different plants. Some fire entire capsules full of seeds like the *Ecballium elaterium*, a plant that is better known as the squirting cucumber.

In this case, when the fruit has matured, the tissues around the seed start to break down, forming a sticky-looking liquid and increasing the pressure in the pod. The tension in the pod reaches a critical level, causing the pod to break away and its seeds to shoot from the capsule.

On the other hand, species like gorse (*Ulex europaeus*) gradually lose water from their pods as they mature, which causes them to become more rigid. Seeds are fired when the tension in the cells holding the pod together increases until the pod splits along established lines of weakness, known as dehiscence. The spotted touch-me-not (*Impatiens capensis*) also works in a similar way, with the pod explosively splitting open upon drying or even when lightly touched, catapulting its seeds for metres in all directions.



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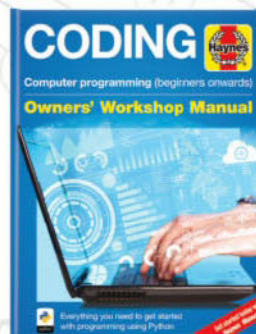
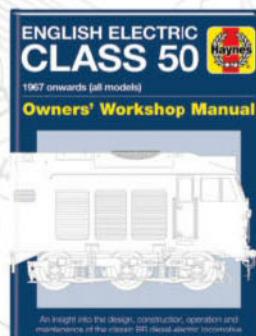
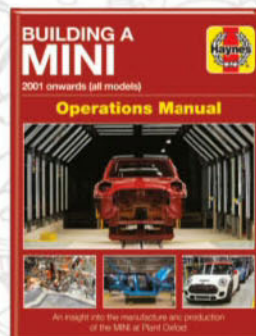
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# Ice cores

Discover the prehistoric secrets held beneath the ice sheets

In order to predict the future of our planet we must first go back in time to unearth the hidden secrets of our icy Earth. Each layer of ice tells a story, exhibiting differences in chemistry and texture.

Falling as a fresh blanket of snow each year, atmospheric gases and other materials are trapped in air bubbles as next year's blanket is laid. Over time every layer of snow is compacted and compressed by more snow until it becomes hardened ice. Much like the rings through a tree trunk, counting the layers throughout the ice enables scientists to age it.

The fundamental idea of using ice cores to read the Earth's climate was achieved by Danish paleoclimatologist Professor Willi Dansgaard in the early 1950s. Extracting ice cores in

Greenland, he found the first tiny air bubbles that archived the world's climate and environmental history.

Those studying the poles today use mass spectrometers to isolate the different gases in ice cores, mainly isotopes of oxygen ( $^{16}\text{O}$  or  $^{18}\text{O}$ ). These gases can help determine the atmospheric composition and temperature at the time the snow fell. For example, the heavier element  $^{18}\text{O}$  requires more heat than  $^{16}\text{O}$  to evaporate into the atmosphere from the ocean's surface.

The ratio of isotopes in ice cores links to the temperature at the time, so heavier isotopes mean higher temperatures. By identifying key patterns in the Earth's atmospheric timeline we can better understand the direction our planet is heading.



Ice cores are taken using rotating drill barrels or thermal drills



Flecks of volcanic ash held in the core can help date each layer

## A laboratory-sized freezer

First set up in 1993 in Colorado, US, the National Ice Core Laboratory is now the central hub for ice core storage. This giant of a freezer measures around 1,557 cubic metres and stores 19,000 metres of ice. The stored samples are collected from Antarctica, Greenland and other regions of northern America. In order to stop the samples from melting and releasing the secrets within, this main freezer is kept at -36 degrees Celsius. Similarly, in the examination room, the ice must remain at a cool -24 degrees Celsius while it is prepared for future study. Known as the 'core processing line', 30–35 metres of ice core can be cut and processed into samples each day.



Ice core samples at the laboratory are cut and sent to research institutes across the US

## Record breaker

Discovered in August 2017, a 2.7-million-year-old ice core has revealed the earliest evidence of Earth's atmosphere. The age of the ice core was determined by measuring the amounts of the elements argon and potassium, as the core's layers were not distinct. It was extracted from a shallow blue ice region of Antarctica known as the Allan Hills. The core revealed that carbon dioxide levels at this time were below 300 parts per million (ppm), significantly lower than today's levels of over 400ppm. In their next venture, the discovery team hope to find a 5-million-year-old sample. It is estimated that a core of that age would show us more about the effects of the warming global climate.

Previously overlooked blue ice could hold much older samples for study

*"Counting the layers throughout the ice enables scientists to age it"*



# HOW TO SAVE A LIFE

How does a trauma team respond when their red phone rings?

## Patient journey

How trauma cases are processed

### Pre-hospital

Paramedics secure the patient's airway and apply pressure to wounds.

### The red phone

A phone call alerts the trauma team leader and preparations begin for the patient's arrival.

### Airways, breathing and circulation

The team clear the patient's airway, support their breathing and stop any bleeding.

### CT scan

The patient receives a scan to reveal any internal injuries.

**"T**he ambulance service ring us on our red phone to say we've got a trauma coming in," Dr Gary Cumberbatch explains. He is the clinical director for emergency services at Poole Hospital NHS Foundation Trust. His trauma team receive around 60 calls a year.

"We have specific criteria to make a trauma call," he tells us. "If you're unconscious from a head injury, that will trigger it. If you're breathing very fast or very slowly following an accident, that will trigger it. If your blood pressure is low, suggesting you've got internal bleeding, or if you've got back or neck pain and you're paralysed, that will trigger it." Dr Cumberbatch's team are reserved for the most serious trauma emergencies.

Most trauma patients go to a Major Trauma Centre. The closest to Poole is at Southampton General Hospital. But if they can't get there within 45 minutes, or they don't have 45 minutes to spare, Dr Cumberbatch's team step in.

The accident and emergency (A&E) consultant takes the lead. "If they're not in this department they get a phone call immediately and are expected to arrive within 30 minutes," Dr Cumberbatch says. There are doctors to perform procedures, nurses to assist, a radiographer to take X-rays and perform a CT scan, and a scribe to make notes. "We automatically call the anaesthetist out from the intensive care unit, as well as the surgeon," he continues. "Someone to put them [the patient] to sleep and someone to do an operation to stop them bleeding." Each team member has a pager so they don't miss the call.

When the patient arrives, the first priority is their airway. Easy to remember, Dr Cumberbatch tells us, because it begins with an 'A'. "If you don't open someone's airway so they can breathe through it, you only have three minutes before they die. That takes priority."

The team use suction to remove any blood or vomit in the windpipe, making a clear passage to the lungs. From then on they need to keep the neck still. "We assume they've all got an injury to the spine," Dr Cumberbatch says.

The next step is breathing. "You may clear the airway only to find that they're not even breathing, or they are breathing but very shallowly. So we'll breathe for them using something called an Ambu bag." This is usually performed by the anaesthetist,

## Vital signs

The trauma team keep track of eight vital signs to check if patients are stable

### Temperature

A thermometer in the ear or mouth checks whether the patient is maintaining their body temperature.

### Respiratory rate

The number of breaths a patient takes is counted for 30–60 seconds.

**"If they're bleeding heavily, they're not getting a scan"**

**Dr Gary Cumberbatch**

### Oxygen saturation

A pulse oximeter measures the amount of oxygen in the blood, also known as 'SpO2'.

### Urine output

A catheter collects urine, revealing how well the kidneys are functioning.

### Level of consciousness

Eye opening, speech and movement checks alert the team to any problems with brain function.

### Pain

Conscious patients are checked frequently for pain and are given morphine if necessary.

### Blood pressure

A blood pressure cuff reveals information about the pressure exerted when the heart is contracting and relaxing.

### Pulse

The patient's pulse is counted for 30 seconds to check that they have enough blood and their heart is pumping strongly.

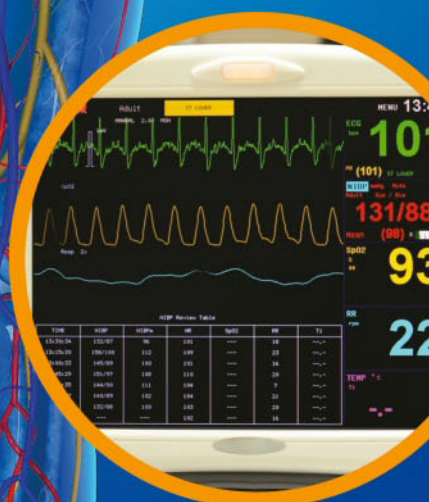
Monitors keep track of heart rate, blood pressure, oxygen levels, breathing rate and body temperature

**Transfer**  
Specialists take over and tend to broken bones, internal injuries or brain damage.

**Poole Hospital**  
Emergency Department



Dr Gary Cumberbatch is the clinical director for emergency services at Poole Hospital NHS Foundation Trust





who pumps oxygen into the lungs through a facemask. If this doesn't help, the next step is life support: a tube goes in through the voice box and a machine takes over the work of the lungs. "To do that we have to give them drugs to make sure that they're deeply unconscious and all their muscles are paralysed," Dr Cumberbatch explains.

Then they can move on to 'C' for circulation. "That means, are they bleeding?" says Dr Cumberbatch. "If they come in and they're losing blood from their leg, then you should press on that even before seeing to the airway. A lot of this experience has come from the military.

"If it's not an obvious wound but their pulse rate is high and their blood pressure is low, we've got to find where they're bleeding from internally," Dr Cumberbatch explains.

"You can bleed in five places," he continues. The patient might be bleeding onto the floor from wounds on their back. Alternatively, the wound could be in the patient's chest or their abdomen. Or it could be that they have broken their pelvis. The fifth possibility, explains Dr Cumberbatch, is a broken thigh bone.

The team need to stop the bleeding to get the patient ready for step 'D', which stands for disability. "You're not allowed to move from one letter of the alphabet to the next until the first one's sorted," Dr Cumberbatch explains. "We can put a probe on their abdomen to see if there's any blood internally. We use a probe on their chest to see if there's a collapsed lung or any blood. Otherwise most patients go through the CT scanner. We stabilise them and then we take them there."

The scanner reveals any internal injuries to the brain or internal organs. But not everyone can go straight away. "If they're bleeding heavily, they're not getting a scan." Instead, the surgeons take them to the operation theatre and open them up, find where the bleeding is and stop it. The patient can only go to the scanner when they are in a stable condition.

Only then can the team move on to 'E'. "That ABCD approach is what we call the primary survey," Dr Cumberbatch explains. "Your assessment is purely to work out threat to life immediately. Fortunately, most patients don't have that, so we move to the secondary survey, where we look for other injuries. That'll be broken arms and legs, missing teeth, internal injuries that aren't causing bleeding, like a perforation of the bowel."

The letter 'E' stands for 'exposing'. [We have to] "Make sure they don't get too cold," Dr Cumberbatch warns. "We work methodically down from the top. It's as important to save lives as it is to pick up other injuries." The trauma team work extremely quickly, aiming to get their patients stabilised and scanned within 20 minutes.

The work can be intensely stressful, especially when the patient is a child. "You can't afford to be



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#### A&E doctor

The doctor surveys the patient, looking at Airways, Breathing, Circulation and Disability.

#### Anaesthetist

The anaesthetist maintains the patient's airway and inserts a tube into their windpipe if they are struggling to breathe.

#### Nurse 2

The second nurse sets up equipment, assists with procedures and checks vital signs.

distracted by emotion," Dr Cumberbatch tells us. "You have to give the child the best chance."

The above describes major trauma but the team at Poole also manage minor injuries. "One of the things I particularly like to treat is crushed fingers. You come in, your nail is hanging off, there's blood. I can numb your finger in 30 seconds flat. Within five minutes your finger is pain free. We take the nail off, repair the nail bed injury, put the nail back on delicately. Wow, looks like a finger again."

The job has obvious challenges, but as Dr Cumberbatch says, "the sweet comes with the bitter". And sometimes the little things provide the biggest rewards.

**DID YOU KNOW?** There are 27 Major Trauma Centres in England. Five only treat children, and 11 only treat adults

## The trauma team

Expert professionals and life-saving equipment surround a trauma patient

### Head

Anaesthetists and airway specialists are positioned at the patient's head.

### Torso

Doctors and nurses surround the patient's chest, arms and abdomen.

### Surgeon

The surgeon is called down to stem any internal bleeding.

### Paramedic

The paramedics accompany the patient into the trauma unit and explain their condition to the team.

### Nurse 1

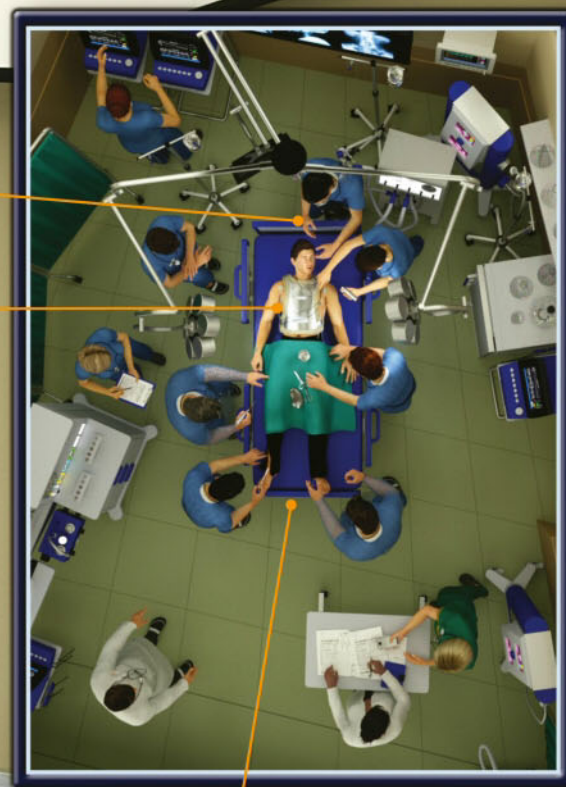
The first nurse cuts away the patient's clothes and inserts IV lines, catheters and chest drains.

### Scribe

The scribe documents everything, recording measurements every five to 15 minutes.

### Feet

The team leader and scribe are positioned near the patient's feet.



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*"The sweet comes with the bitter"*  
**Dr Gary Cumberbatch**

Paramedics are often the first on the scene after a major trauma incident



# Planet formation

HOW DO ROCKY PLANETS FORM THROUGHOUT THE UNIVERSE?

## BACKGROUND

When gases such as hydrogen, helium and other ionised gases combine with space dust, they form an interstellar cloud. Known as a nebula, this giant cloud begins to collapse under its own mass. Gravity then causes this dust and gas to be continuously dragged into the centre of the cloud, making the core very hot and dense. This forms an object called a protostar, which will eventually develop into a new star. Around the protostar, the collapsing cloud forms a rotating disc of material. It is from this 'protoplanetary disc' that new planets are born.

## IN BRIEF

As a giant spinning ball of dust circulates around the gravitational pull of a new star, the ball begins to flatten and forms a rotating disc-shaped dust cloud called a protoplanetary disc. This works in a similar way to a ball of dough flattening when it's tossed and spun in the air to make a pizza.

In order to form new rocky planets little bits of dust need to combine to form clusters. Particles in the disc begin to clump together and as they continue orbiting the star they attract the surrounding material and continue to grow bigger. Under the force of gravity these particles continue to collide into each other to form the beginnings of a planet, known as planetesimals. Over time the star-orbiting planetesimals continue to collide with each other and grow, eventually becoming planetary embryos/protoplanets.

A chance collision between the protoplanets initiates the final stages, and what often remains are multiple fully formed smaller, rocky planets.

## SUMMARY

Tiny particles of dust within protoplanetary discs can collide and stick together. These clumps continue to accumulate and collide to form larger rocky bodies, eventually becoming planets.

## Building planets

How does a rocky world form from dust?

1



2



3



4



### 1 Protostar

Collapsing and compressing gases within a nebula form the beginnings of a new star.

### 2 Dust clouds

Fine grains of dust collect and orbit the newly forming stars gravitational pull, creating a spinning hot disc of dust.

### 3 Planetesimals

Due to the gravitational pull of the protostar, dust grains clump together to form large bodies of rock.

### 4 Protoplanets

Planetesimals collide and recombine to form larger bodies of rock, eventually leaving planets behind.

## GIANT PLANETS

Rocky planets aren't the only types of worlds that exist out there in the universe. Often the planets furthest from their parent star are gas giants, initially formed from hydrogen and helium.

While the atmosphere of Jupiter and Saturn reflects this, Uranus and Neptune are referred to as the ice giants as they are composed of 'icy' water, ammonia and methane. There are different theories as to exactly how these planets form and

what is at their cores. Jupiter is the most controversial of the group, inspiring very different opinions.

In the same way that rocky planets start to form, the predominant theory is that Jupiter also has a rocky core. But other scientists believe that there could be a liquid mass at the centre of this colossal planet. These questions are essential if we are to unravel the mysteries of the universe.



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# The gut-brain axis

How does the bacteria in your gut act like a 'second brain'?

**W**e all know that our mood and behaviour is controlled by the brain, but are we overlooking another important aspect of our neurobiology?

There is an increasing amount of evidence to suggest that the activity of bacteria in your gut can significantly affect your brain. This relationship is called the gut-brain axis, and while its exact mechanisms and significance haven't been fully figured out, it is thought that the microbes colonising your digestive tract are responsible for complex interactions between your digestive system and the nervous, endocrine and immune systems.

Your intestines are filled with bacteria. When you think of bacteria you probably think of the germs that make you sick, but we actually have a lot to thank these tiny microorganisms for. We rely on 'good' bacteria to help break down food, produce vital nutrients and defend us against harmful bacteria. But this could just be the tip of the iceberg. Scientists speculate that gut microbes can send signals to the brain via three different methods.

The first involves bacteria releasing neurotransmitters (chemicals that help to

transmit nerve impulses) to trigger the neurons in your digestive tract, which in turn send signals to your brain via the vagus nerve. Some studies have shown that certain species of gut bacteria can produce serotonin, an important neurotransmitter that plays a role in regulating your appetite and mood.

A second proposed method is that microbes in the gut produce molecules called metabolites as by-products when they break down our food. These metabolites can stimulate an increase in the production of neurotransmitters by cells that line the gut (epithelial cells), which activate the vagus nerve. For example, a recent study found that some gut microbes can produce the fatty acids butyrate and tyramine, which promote the production of serotonin by certain cells.

The third hypothesis is that gut bacteria can influence the brain indirectly by triggering the immune system. Gut bacteria can stimulate immune cells to produce small proteins called cytokines, which travel through the bloodstream to the brain. It is thought that these proteins can influence the development and activity of microglia (the brain's immune cells), which are responsible for removing damaged

cells at an injury site. Researchers believe microglia also play a role in the regulation of appetite and metabolism.

Although there are few human studies at the moment, animal studies have linked the activity of gut bacteria to a variety of conditions, including Parkinson's disease, obesity, depression, anxiety, schizophrenia and cardiovascular disease, and they may also cause certain types of strokes.

While much more research will be needed to further investigate these initial findings, if links are confirmed it could revolutionise how we treat certain neurological disorders. Perhaps in the future doctors will be prescribing probiotic diets to supplement treatments.

## Neurotransmitter production

Some bacteria have been found to stimulate the production of serotonin — a neurotransmitter that helps regulate mood — by cells in the intestinal wall.

Intestinal wall

## Positive influences

Probiotic supplements with good bacteria and prebiotic foods full of fibre that nourish our good bacteria can help to promote a healthy microbiome.

Beneficial bacteria

Your intestines contain a vast network of nerves (shown left, in yellow), providing communication links between your brain and gut

## Bacterial boost

Two recent studies have shown that patients' gut bacteria can influence how well they respond to particular cancer treatments. Both studies, one from France and one from the US, collected data from patients undergoing immunotherapy, which help to combat cancer by enabling the body's immune cells to recognise and attack tumours.

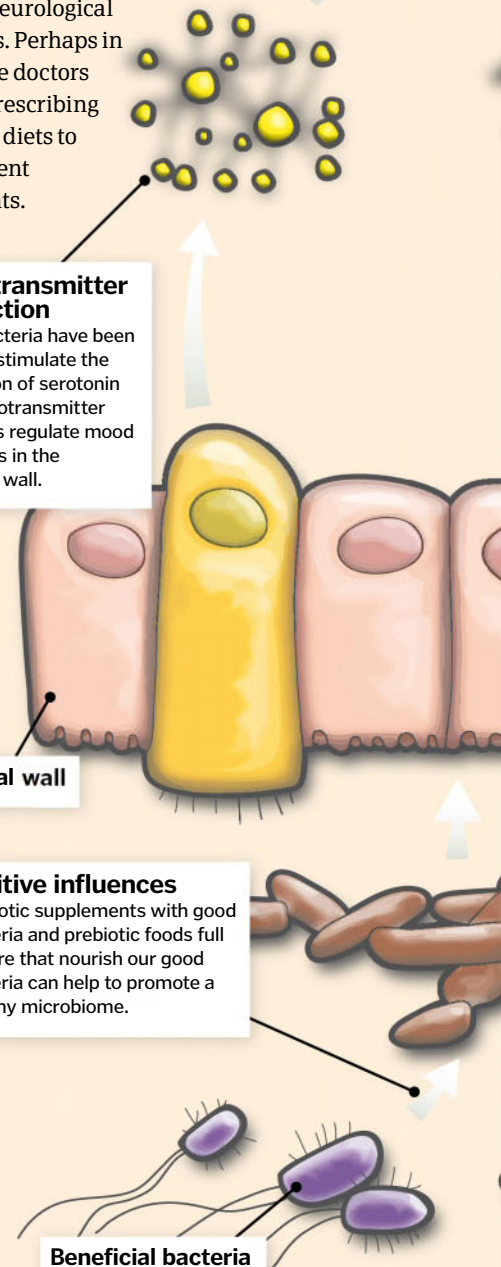
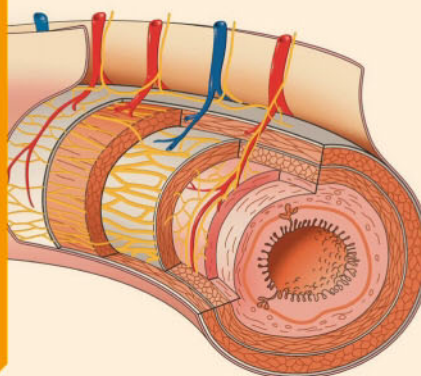
The French study involved 249 patients receiving immunotherapy for kidney, bladder or lung cancers, 69 of whom had taken antibiotics for routine infections. Antibiotics disrupt the microbiome, affecting both 'good' and 'bad' bacteria. On average, patients who took antibiotics during treatment were more likely to have relapses and did not survive as long as those who didn't. The authors then compared the differences in the patients' microbiomes and found that the presence a species called *Akkermansia muciniphila* was linked to the improved immunotherapy results.

The US study also compared the different gut bacteria present in 112 melanoma patients. Patients who responded well to treatment were more likely to have more diverse microbiomes and higher numbers of certain beneficial species including *Clostridiales* and *Faecalibacterium*. Patients with more of these 'good' bacteria were found to have more cancer-killing immune cells in their tumours.

The results from both studies hold a lot of promise. The hypothesis is that by supporting a healthy microbiome, immunotherapy is more likely to be effective at shrinking tumours.



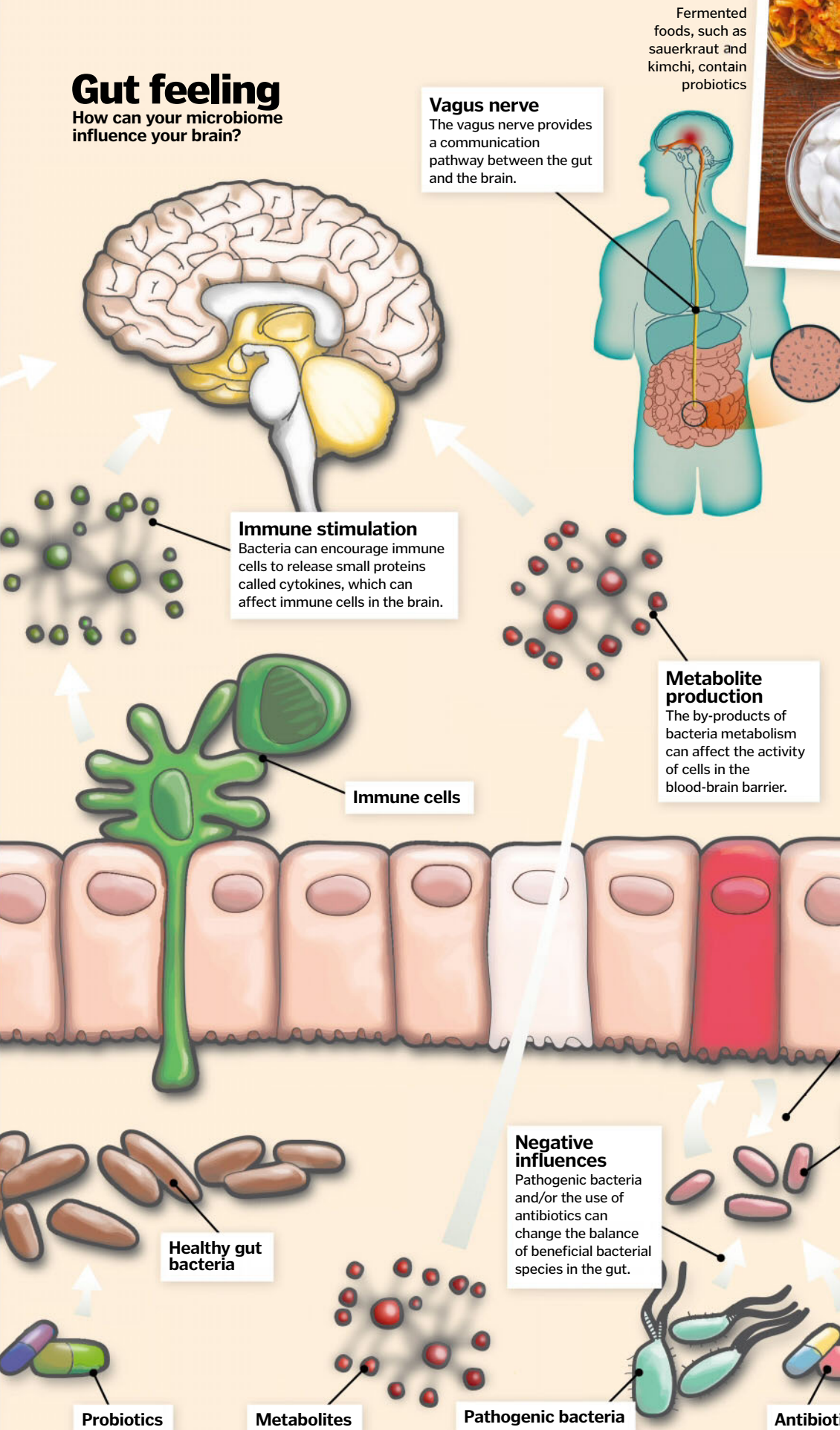
Scientists are only just beginning to understand the impact your microbiome can have on your brain



**DID YOU KNOW?** There are over 100 trillion microbes in the human gut!

## Gut feeling

How can your microbiome influence your brain?



## Probiotics and prebiotics

Given the potential impacts our gut bacteria can have on our overall health, the old adage that states 'you are what you eat' is becoming increasingly appropriate.

We can promote the growth of good bacteria through our diets by incorporating probiotics (foods containing live good bacteria) and prebiotics (foods containing beneficial plant fibres). Probiotics can be found in certain yoghurts, cheeses and fermented foods. Prebiotics, on the other hand, are used as a food source for beneficial bacteria to grow and survive in the gut. When they digest the fibre we eat from vegetables, nuts and fruits they excrete short-chain fatty acids as waste products, which are great for nourishing our intestines and reducing inflammation.

Research suggests we need a diverse range of bacteria to have a really healthy gut, but modern high-fat and high-sugar diets have been found to decrease the number of different species living in our intestines.

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# Hair bleach

How does hair lightening work?

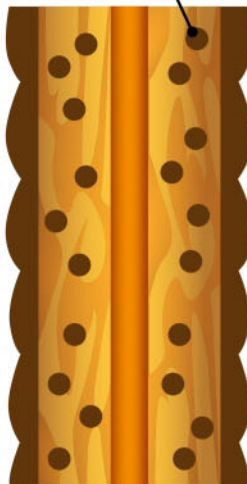
**H**ydrogen peroxide, a type of bleach, has a variety of applications in industry, one of which is to remove colour from hair. Hair is made from a tough protein called keratin, the same material that makes up your nails and the outer layer of the skin. Hair colour is determined by the ratio of the pigments eumelanin (responsible for black and brown pigments) and pheomelanin (which produces yellow and red pigments). Without either type of melanin, hair becomes grey or white.

Bleach lightens hair by oxidising the melanin molecules. The melanin pigment is still present within the hair, but once oxidised it is colourless, leaving just the pale yellow tint of the keratin protein. Bleach is particularly useful in changing darker hair to lighter hair, but if not used properly it can lead to damage. If left on for too long, bleach will react with the moisture within the shaft of the hair, leaving it dry, brittle and frizzy.



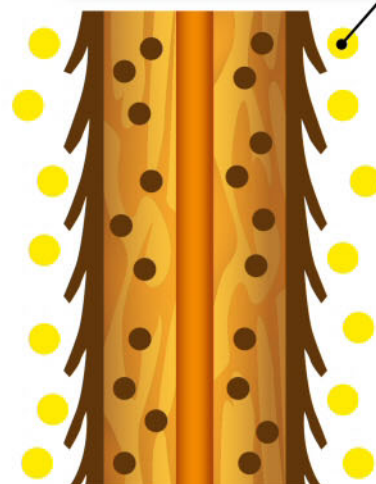
## Normal hair

Melanin molecules within the hair are responsible for its natural colour.



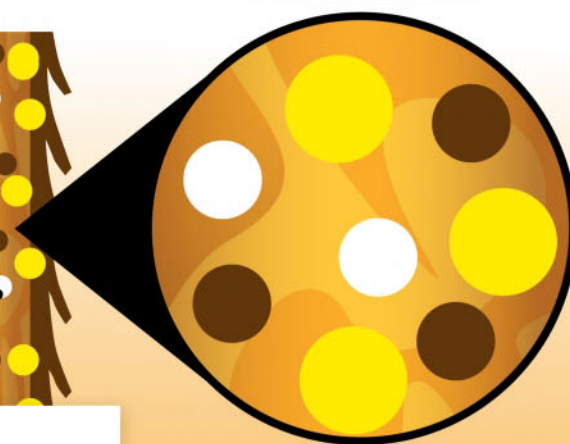
## Bleaching

When exposed to bleaching agents such as hydrogen peroxide, the hair cuticles open, allowing the bleach molecules to enter the cortex (where natural hair pigment is found).



## Oxidation

The bleach molecules oxidise the melanin in the hair, making them transparent. As bleaching progresses, the hair becomes lighter and changes in this order: black – brown – red brown – orange – light yellow – very light yellow.



# Colour-changing hair tech

How clever chemistry can help create hair colour that reacts to heat

**T**he 1960s saw a creative boom of colourful products that led to the invention of thermochromic dyes in the 1970s, dyes that react to heat and colour.

We were first mesmerised by colour-changing mood rings that swirled through a spectrum of colours as our body temperature changed, and it wasn't long before there was an explosion in thermochromic products. Now companies such as The Unseen and Pravana have combined science and art to create hair dyes that will respond to the temperature of your body or the

environment and change colour. You could step out of the front door, and as the sunlight warms your hair it will change from platinum blonde to pink, before a cool breeze catches your hair and it reverts back to blonde. It sounds like magic, but behind this advanced beauty product is some serious chemistry.

The technology relies on carbon-based molecules that are able to undergo reversible reactions. When the temperature rises above a certain point the molecules react and change shape, which alters how the molecules absorb

Pravana's Vivids Mood Colour is the first heat-reactive pigment available on the market



and reflect light. Because different wavelengths of light are absorbed and reflected by the molecules, this alters the colours we see. Since the reaction is reversible, hair colour will revert back to normal when cooled.





HOW IT  
WORKS

# BATTLESHIPS

HOW IT  
WORKS

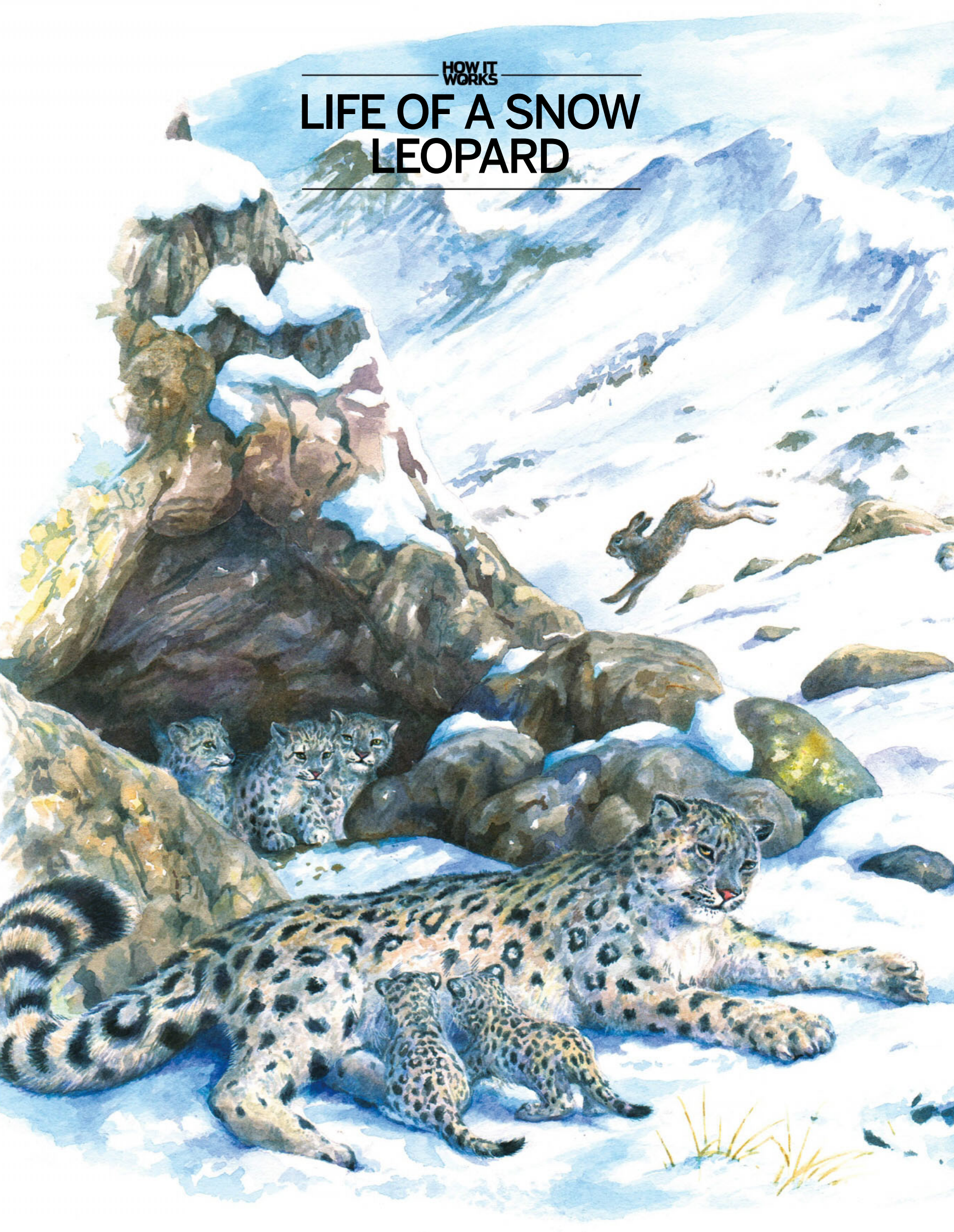
# COULD LIFE EXIST ON EUROPA?





HOW IT  
WORKS

# LIFE OF A SNOW LEOPARD







TOP  
10

# ASTRONOMICAL DISCOVERIES

The revelations that not only changed the world but challenged the way we see our existence and our place in the universe

1

## GRAVITATIONAL WAVES

**T**he existence of gravitational waves was first predicted in 1916 by Albert Einstein, who suggested that when two massive accelerating objects collide they cause ripples to be discharged through space, similar to the ripples seen when a pebble is thrown into water. Almost 100 years later scientists were still struggling to directly detect them, something even Einstein himself doubted could be done. When a wave passes through Earth it is squeezing and stretching

the fabric of space, but as these differences are so tiny most instruments have not been able to detect these changes until recently.

Named LIGO (Laser Interferometer Gravitational-Wave Observatory), this laser-and mirror-based technology is sensitive to the smallest ripples through space-time. This pioneering US research facility uses two four-kilometre L-shaped detectors located in Livingston in Louisiana and Hanford in the state of Washington.

On 14 September 2015 the moment the scientists had been waiting for came when a gravitational wave rippled through the Earth caused by the violent crash of two black holes over 1 billion years ago. The first wave passed through the Livingston facility before then being detected seven milliseconds later in Hanford, 3,000 kilometres away. Not only did this discovery prove that Einstein's theory was right, but it will revolutionise our very understanding of the entire universe.

## 2 JUPITER'S MOONS

More than 588 million kilometres from our Earth an orange-and-yellow banded gas giant orbits the Sun. Though we have always been close (relatively speaking) neighbours to Jupiter, it wasn't until 1610 that we discovered that this huge planet has multiple moons. It was the Italian astronomer Galileo Galilei that identified the celestial bodies orbiting Jupiter and named them Io, Europa, Ganymede and Callisto.

At this time in history people were still struggling to accept that we were not at the centre of the universe. Galileo's landmark discovery changed the way we viewed our universe and challenged our place within it. We realised that if some celestial bodies orbited planets that weren't us then that meant we are really not that special.



The Galilean moons of Io, Europa, Ganymede and Callisto (top to bottom) are just four of Jupiter's possible 69 satellites

## COSMIC MICROWAVE BACKGROUND RADIATION

3

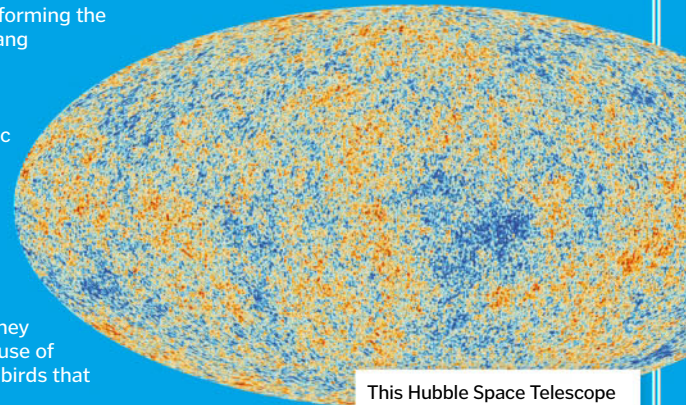
In the mid-1960s astronomers Arno Penzias and Robert Wilson discovered cosmic microwave background radiation. This radiation is present in tiny quantities

throughout the entire universe as the residual radiation left from the birth of the universe. Their discovery was of enormous cosmological significance, transforming the (at the time) controversial Big Bang Theory into the scientifically accepted explanation of the birth of the universe.

Like many of the best scientific discoveries, it happened almost accidentally. While working with a very sensitive radio telescope at Bell Labs in New Jersey, US, they noticed a mysterious hissing sound coming from all directions. Frustrated by the interference, they did their best to work out the cause of the sound, even removing some birds that

had made a nest in the antenna, before realising they were onto something big. They had discovered the echo of the explosion that caused the beginning of the universe.

The background noise Penzias and Wilson detected (shown below as observed by the Planck satellite in 2013) was the sound of the birth of the universe



This Hubble Space Telescope photograph shows one of the galaxies in a recent study conducted to further refine Edwin Hubble's calculations.

## THE UNIVERSE IS EXPANDING

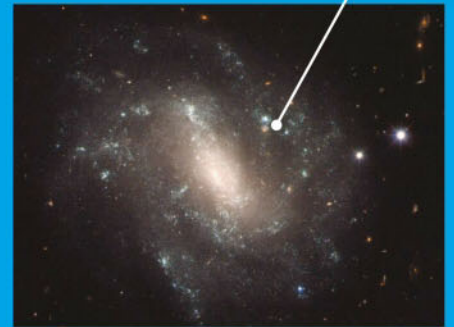
4

Edwin Hubble was the first to discover other galaxies beyond our own Milky Way, but it turns out that this discovery alone wasn't impressive enough to get a telescope named after him! Hubble actually made an even greater contribution to science that changed the way we understand the origins of our universe.

In 1929 Hubble discovered that all galaxies seemed to be moving away from us and the ones furthest away are moving the fastest — a relationship now known as Hubble's Law. This was the first evidence indicating the universe is expanding.

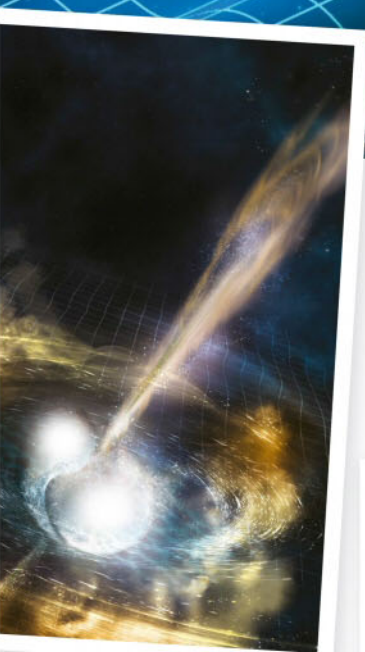
Hubble took long-exposure photographs of the spectra of faint galaxies using a telescope and measured the amount they shifted to

calculate their speed. He then plotted the speed of the galaxies against their distance and noticed the interesting relationship between the data. This really had scientists thinking. If the universe is expanding it must have been smaller in the past, so it must have started from one small point. This formed the basis of the Big Bang Theory.



## Neutron star collision

On 17 August 2017, LIGO detected gravitational waves from a neutron star merger



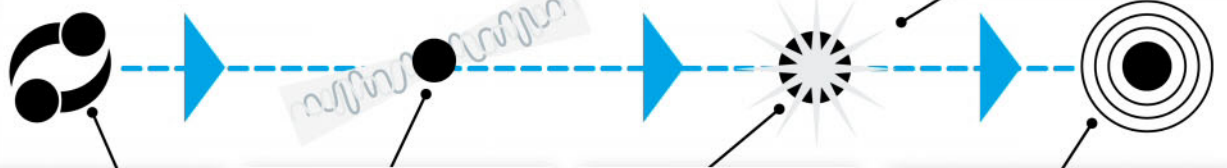
**Gravitational wave signal (12:41:04 UTC)**  
A gravitational wave signal is detected by LIGO after binary neutron stars collide 130 million lightyears away.

**Gamma-ray burst (+2 seconds)**  
The intense burst of gamma-ray radiation produced just after the merger is detected almost immediately after the first signal is received. It is this gamma-ray burst that suggests the wave was caused by the merging of two neutron stars.

**Optical (+10 hours, 52 minutes)**  
At this point the merger can now be seen visually as a new bright source of light in another galaxy called NGC 4993, as deteriorating neutron-rich material creates a glowing kilonova.

**X-ray (+9 days) and radio (+16 days)**  
As material moves away from the merger it produces a shock wave in the space between the stars through the universe. This can be detected in the form of X-ray and radio emissions, which can last for years.

**Infrared (+11 hours, 36 minutes) and UV (+15 hours)**  
Infrared and bright UV are detected in the hours following the merger.





# ORGANIC MOLECULES ON COMETS

5

NASA-funded researchers announced in 2016 that the Rosetta spacecraft had discovered some building blocks of DNA in the thin atmosphere of the comet 67P/Churyumov-Gerasimenko.

This breakthrough was the first direct and repeated detection of the amino acid glycine and suggests that not only could comets be responsible for assisting the origins of life on our planet, but they could also be responsible for delivering organic molecules to other worlds.

*"Comets could deliver organic molecules to other worlds"*

## THE PREVALENCE OF DARK MATTER

6

Vera Rubin not only made a huge cosmological discovery in the 1970s, but she also founded an entire subject in the process.

She noticed a difference between the predicted angular motion of the galaxies and their observed motion by studying galactic rotation curves and determined that visible matter alone wasn't enough to explain the speed at which stars rotate, and it wasn't possible that normal matter could generate enough gravity to hold galaxies together.

Rubin proved that most of the mass in the universe does not

emit, reflect, or absorb light, and she named this dark matter. Though it is still a mystery as to what exactly dark matter is, we know that it isn't made from protons and neutrons like 'normal' matter. It is thought that approximately 27 per cent of the entire universe is made from this mysterious substance, which is expected to consist of subatomic particles that we have not yet been able to detect.

This Hubble image shows a huge ring of dark matter surrounding the centre of the galaxy cluster CL0024+17

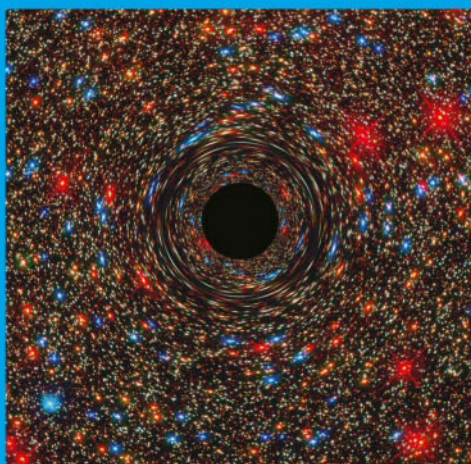


## BLACK HOLES

7

The mathematical concept of black holes is one that has been around for hundreds of years, but it was always impossible to find evidence for their existence before the Hubble Telescope.

Designed to take clear pictures of the deepest parts of space, this incredible feat of engineering was launched into space in 1990 and has provided images showing black holes' immense gravity — their ability to pull matter from around them. Black holes are thought to form when massive stars die, imploding from their own weight and have such a strong pull of gravity that not even light can escape, which is why we can't directly detect them with conventional methods.



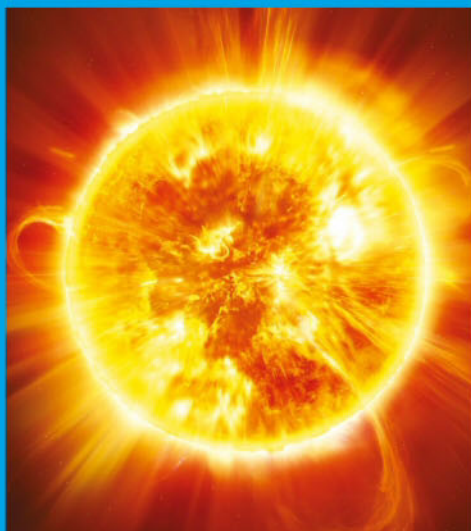
The Hubble Telescope is responsible for a wide range of scientific discoveries, including finding evidence to support the existence of black holes (artist's concept)

## STARS ARE POWERED BY FUSION

8

Around 1920 Arthur Eddington, an English mathematician, physicist and astronomer, proposed that stars obtain energy by the nuclear fusion of hydrogen to form helium.

He formulated a theory suggesting that heavier elements can also be produced when a star runs out of hydrogen.



9

## EXOPLANETS

On 9 January 1992 Aleksander Wolszczan and Dale Frail announced their discovery of two planets orbiting the neutron star PSR B1257+12. These planets turned out to be the first confirmed exoplanets — planets that orbit a

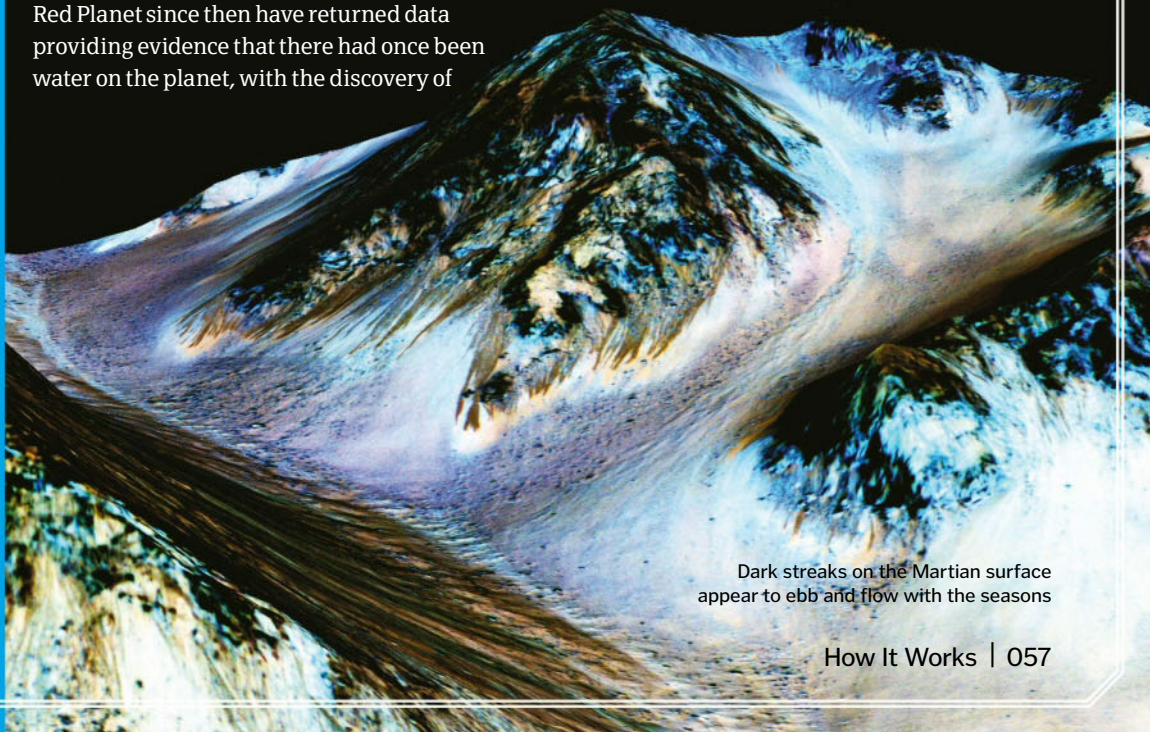
star outside of our Solar System. They're difficult to detect because they are not very bright and they are very far away from us. At the time of writing there are 3,550 confirmed and 4,496 candidate exoplanets.

## 10 WATER ON MARS

Shortly after humans first landed on the Moon in 1969, NASA's Viking mission took one more giant leap by landing a rover on Mars in 1976.

Many of the rovers and satellites sent to the Red Planet since then have returned data providing evidence that there had once been water on the planet, with the discovery of

ancient riverbeds and remnants of vast flooding. And in 2015 NASA's Mars Reconnaissance Orbiter (MRO) provided conclusive evidence that liquid water still flows intermittently on Mars.



Dark streaks on the Martian surface appear to ebb and flow with the seasons



# The Pencil Nebula

Looking more like the doodles on a celestial notepad, how did this strange nebula form?

**N**ebulas come in all shapes and sizes, often appearing as a tenuous cloud of gas. However, 815 lightyears away in the constellation Vela sits a nebula often said to resemble a witch's broom. However, magical as it may appear, this nebula was born in the same way as any other.

When a star grows to a point where it has reached its nuclear fusion limit, it fights a losing battle with gravity as gravitational forces struggle to balance the outward pressure generated by nuclear fusion. Eventually, the star's core collapses and violently explodes in a supernova.

Around 11,000 years ago, anybody on Earth who happened to be gazing toward Vela would have been able to spot the star that created the Pencil Nebula. All of a sudden, the star became 250-times brighter than Venus in the night sky; for a time it would have even been visible in the day.

As a star goes supernova it ejects gaseous debris known as the supernova remnant, which produces an expanding gas cloud. This debris is dispersed into the interstellar medium at supersonic speed, where it then collects and forms this new cosmic real estate. At the final boom of a supernova explosion shock waves pulsate through space, sweeping through the gaseous material already emitted.

The Pencil Nebula was part of a shock wave travelling at millions of kilometres per hour that was sent crashing into dense gas regions, causing it to form its iconic filaments and ribbon-like appearance.

The energy from the shock wave would have heated the dense gases to millions of degrees Celsius, and after they cooled down the nebula began to glow, making it easier for telescopes such as the Hubble to spot it.

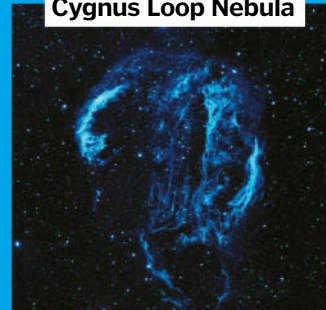
Undulating sheets of dense gas make up the Pencil Nebula, which spans 0.75 lightyears across

*"Shock waves pulsate through space, sweeping through the gaseous material"*

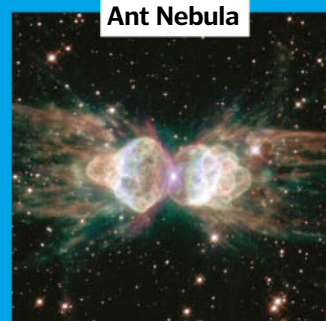
## Strange shapes

Discover the other bizarrely shaped nebula floating around the universe

**Cygnus Loop Nebula**



**Ant Nebula**



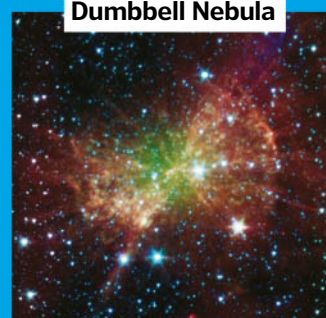
**Helix Nebula**



**Rosette Nebula**



**Dumbbell Nebula**



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# MONSTER TRUCKS

Discover the incredible engineering behind  
this super-sized motorsport

Every year millions of fans around the world travel to watch these magnificent machines race, crash and roar, captivated by their extraordinary power and strength. Once on the sidelines, these mechanised behemoths are now the main attraction.

The sport began with modified pick-up trucks with larger suspension and bigger tyres, but monster trucks have evolved into complete custom builds with giant wheels and impressive ground clearance, as well as custom-built tubular chassis with fibreglass bodies. This can attach to the chassis separately, allowing for easy removal when damaged.

These gravity-defying giants are durable monsters designed to bounce, crash and roll over. Monster trucks captivate audiences by crushing everything in their path. These truck titans typically weigh around 4.5 tons and are capable of making jumps ten metres high and 60 metres long. Few can beat Bigfoot, one of the first ever monster trucks, which managed to leap over a 727 jet plane!

Amateur monster truck driving sounds like a fun hobby, but competition rules mean really ramping up the game. If a driver wants to race, their monster truck must adhere to specific rules. The vehicle must be at least 3.6 metres tall and 3.6 metres wide and fitted with giant 209-kilogram BKT 168-centimetre off-road tyres. These tyres have extra-deep treads to provide optimal traction, which is needed to keep such a colossal truck stable, under control and safe.

Monster trucks usually battle against

each other in the form of two versus two racing before a freestyle round, where the mighty machines have the opportunity to show off their spectacular stunts as they take on aerial jumps, wheelies and donuts. It's this freestyle round where drivers demonstrate the power of a monster truck, as caravans, buses and other obstacles are placed in their path to be crushed.

### HOW TO BUILD A MONSTER TRUCK

A monster truck starts life as a donor body taken from another vehicle, usually a four-wheel-drive pick-up truck. Most components will be upgraded to be more durable and robust, but it is

**"These gravity-defying giants are durable monsters designed to bounce, crash and roll over"**



Despite their size monster trucks are equipped to handle tight turns

The 12-passenger Sin City Hustler is the longest monster truck and was designed as a monster truck limousine for Las Vegas tourists



One of the most influential and iconic monster trucks of all time is Grave Digger, with its famous black graveyard paintwork and wild reputation

## Monster trucks in the record books

### First monster truck back flip

It takes skill and a lot of guts to flip a monster truck backwards in the air. There are claims that people have achieved it outside of competitions, but the Guinness World Record-approved first was successfully performed at Jacksonville Monster Jam by Canadian Cam McQueen in February 2010.

### Fastest monster truck

The Raminator doesn't let its giant size and heavy tyres slow it down. Mark Hall broke the record three times in Austin, Texas in the US in December 2014, with each of his runs faster than the one before. On his last attempt he achieved a whopping 159.49 kilometres per hour!

### Longest monster truck

Measuring in at an enormous 9.75 metres, Sin City Hustler was built as a monster truck limousine by Brad and Jen Campbell of Big Toyz Racing.

### Longest ramp jump

The sky's the limit for the approximately 4,500-kilogram Bad Habit monster truck. In September 2013 in Columbus, Pennsylvania, US, driver Joe Sylvester successfully ramp jumped across 72.42 metres!

### Largest monster truck

The largest ever monster truck was built in 1986 and is known as Bigfoot 5. Standing at an incredible 4.7 metres and weighing in at an impressive 17,200 kilograms making it the world's heaviest monster truck. The three-metre-tall tyres were taken from a huge vehicle used in Alaska by the US Army.





helpful if the donor body has an engine and transmission so that some of the parts (including mounting brackets) can be reused.

Parts are upgraded with more heavy-duty replacements in order to transform the truck into a true monster. Often these replacements are taken from ex-military vehicles to ruggedise the steering axles and rear differentials. The suspension is raised an additional 0.9 metres to 2.4 metres to give good ground clearance and to accommodate the giant wheels. An upgraded engine is essential, as well as transmission and transfer-case components suitable for high-impact use. This supplies the horsepower needed to move such a mammoth machine.

### SAFETY

Monster trucks crash, they're built to, but this means the safety of the drivers and their fans requires special equipment. Perhaps the most important feature is that monster trucks are equipped with three shut-off switches to quickly turn off the electrics: one within reach of the driver, another in the rear of the truck, and a remote ignition interrupter that allows officials to shut down the engine using a handheld device.

These systems are in place so in the event of a truck rollover the risk of fire is minimised, but they can also be used if the brakes fail or the vehicle appears uncontrollable (and unsafe). Generally, internal moving parts of the truck are shielded to prevent injury, and any high-pressure components are restrained with straps.

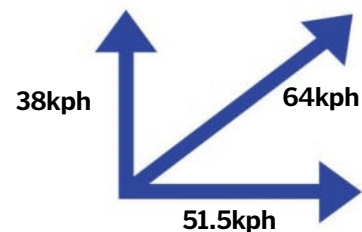
Roll bars and safety cages have to be installed to protect the driver, but drivers are still required to wear specified protective equipment to compete in monster truck competitions, which include a helmet, fireproof suit and a five-point safety harness, as well as head and neck restraints to prevent head injury. Most drivers sit in the centre of the cab, which is shielded with a polycarbonate screen to protect them from stones, mud or debris from the track.

## Monster tricks

How does a monster truck perform a stunt jump?



World Champion Tom Meents attempts a never-before-done front flip of his Monster Truck, Max-D, at MetLife Stadium on 13 June 2015 in East Rutherford, New Jersey



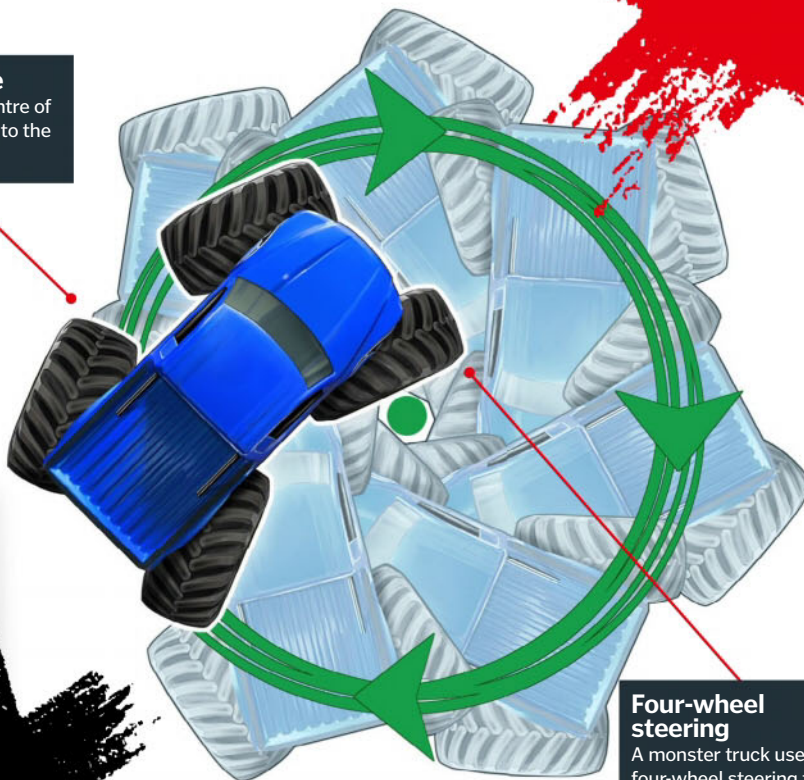
### Launch speed

In this example, the vehicle accelerates towards the 45-degree ramp, reaching 64kph at launch.



### Lean angle

The truck's centre of gravity moves to the outer tyres.

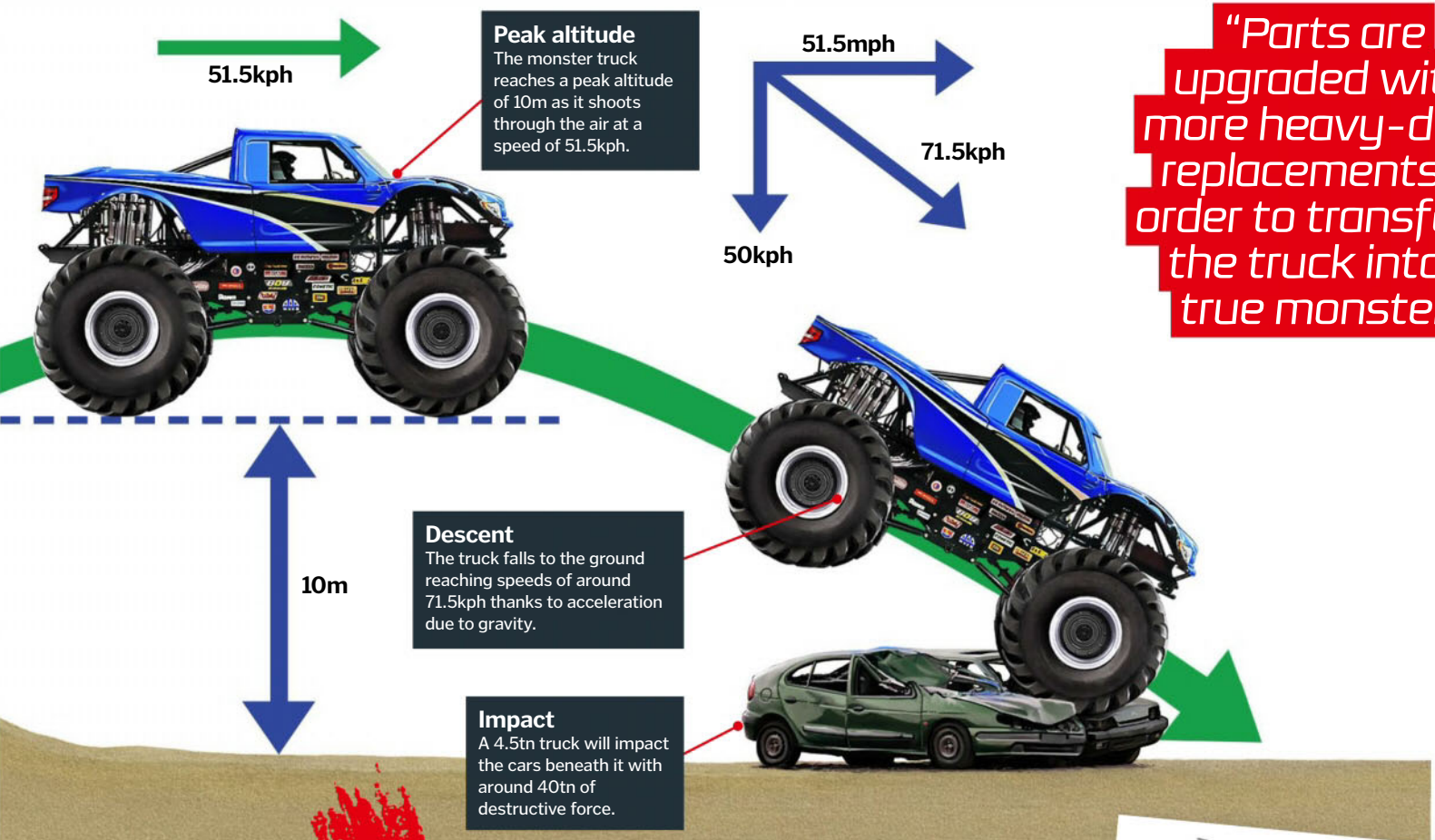


### Four-wheel steering

A monster truck uses four-wheel steering to create tight circles, and the vehicle whirls around its inside front wheel.

Monster trucks can land on other cars with such extreme force they can flatten them





## Monster trucks to the rescue

When 24.5 trillion gallons of rain fell on the US Gulf Coast during Hurricane Harvey in August 2017, tens of thousands of people had to be evacuated from their homes.

Over 200 boats, 300 lorries and 600 people were involved in the efforts to help the flood victims. Joining them were Josh James and his friends from the dirt racetrack Rednecks with Paychecks. These volunteers pulled together and organised their fleet of monster trucks to help in the relief effort. With their trucks standing three metres from the ground, they tackled the fast floodwater and were able to keep their engines free from water where other vehicles would be immobilised.

The makeshift rescue team worked to free emergency vehicles and take them to higher ground, and also helped people stranded on the top floors of their homes get to safety.



Monster truck Old Habits helps residents move a generator in Port Arthur, Texas on 1 September 2017

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# The shipping forecast

150 years after its maiden broadcast, the first public weather forecast system is still responsible for saving lives at sea

In late October of 1859 the iron-hulled Victorian ship *Royal Charter* was returning from Australia to her home in the UK when she found herself dangerously close to the shoreline as winds began to pick up speed. The captain dropped the anchors and cut the masts in an attempt to prevent disaster, but within a few hours the ship had been ripped apart and submerged, leaving over 450 people dead.

The tragedy troubled Robert FitzRoy, a pioneering meteorologist who believed that he could have predicted the storm responsible for

the tragedy, preventing the ship from heading into dangerous waters. In February 1861 the first shipping forecast was given after he introduced a storm warning system using an electric telegraph. The system has developed over the past century and has remained an integral part of keeping people safe at sea.

Today, the shipping forecast is produced by the Met Office and aired on BBC Radio 4 on behalf of the Maritime and Coastguard Agency. There are dedicated teams of meteorologists operating 24 hours a day, seven days a week,

every day of the year. They look at data and observations, monitor charts and produce forecasts every six hours. They provide weather forecasts for all the waters around the British Isles, stretching from southeast Iceland in the north down to Trafalgar in southern Spain.

These waters are divided into 31 sections known as sea areas, providing sailors with accurate weather predictions. The forecast is always read in the same format and the same order, starting with Viking and moving clockwise around the Isles.

## The shipping forecast

What does the information on the shipping forecast mean?

### Wind direction

The direction from which the wind originates.

### Wind strength

The strength of the wind using the Beaufort scale.

### Forecast area(s)

Forecasted areas (outlined on the map, right) are quite often grouped together.

Southeast Iceland, Faeroes

Northerly 6 or 7

Showers

Moderate

### Visibility

An analysis of how visible the seas are in the area.

### Precipitation

The type of precipitation (rain/snow/sleet) to be expected in the area.

© Illustration by Jo Smolaga, Thinkstock



The shipping forecast is always read in the same format to accurately convey information to listeners





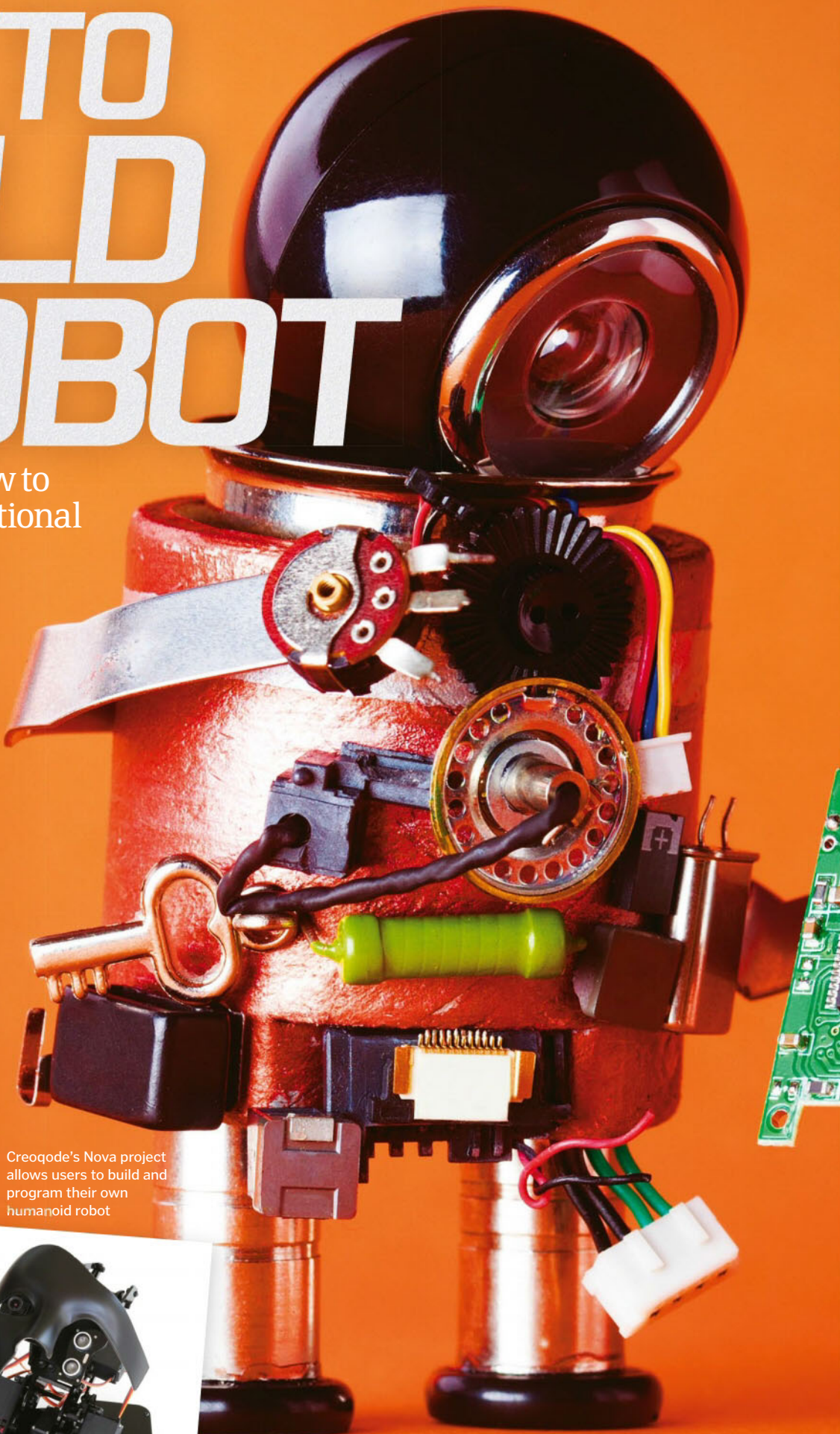
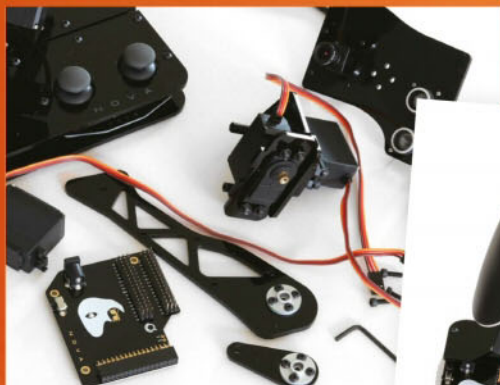
# HOW TO BUILD A ROBOT

Get inspired and learn how to create your very own functional mechanical masterpiece

For every new generation of children there seems to be an iconic film featuring a robot companion. For today's adults it was the brilliant *Short Circuit*, and for children it's Disney's excellent *Big Hero 6* or the *Transformers* franchise. We'd once watch these movies with a sense of longing, quietly wishing we had a robot of our own to join us on our adventures. But now we must wait no longer, as it's easier and cheaper to construct our own robots than ever before! So why don't we get started?

There are several companies that offer simplified robotic assembly packages, with the focus on introducing young children to robot construction. However, to really expand your knowledge and skill set and develop a hunger for building more complex machines, it's best to build a DIY robot from scratch. For this, the first thing you'll need to find is a workshop. Ideally this would be at your local school or college, but if you can get your hands on the essential materials and tools then you could work from your garage at home.

Creoqode's Nova project allows users to build and program their own humanoid robot



Once you've got your base of operations, tools and safety gear all sorted, then you can begin designing your machine. It's always sensible to start simple and work your way up. On the right we've listed some design features that a seasoned builder may wish to consider, but to start with your goal should be to get your simple robot working. Despite its simplicity, your first robot may well be the most challenging you ever create, but it may also be the most rewarding.

By building robots you can improve your skills in mechanics, electronics and programming, all while having fun. Plus, as an added bonus, you get a robot companion as a reward! So turn over the page when you're ready and you can get started on building your very first homemade robot creation.



The study of robotics is likely to play an increasing role in schools

## Designing your machine

Which features will you want to include in your robot?



### Locomotion

Wheels will provide extra speed on flat ground, but for climbing rocky inclines a stable quadrupedal may be the way to go.



### Sensors

Some robots have sensors for analysing objects. You could equip your bot to recognise infrared and ultraviolet light.



### Size

When it comes to robots, bigger isn't always better. Small machines like the Robot Cockroach can slip through tight gaps.



### Strength

Hydraulic pressure, which is the system used by cranes to lift extreme weight, could make your robot a fearsome force.



### Equipment

Your bot may need to carry equipment. One useful item could be the University of Texas' 'self-healing' gel.



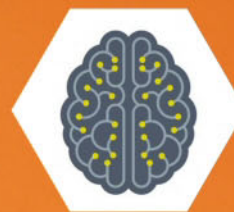
### Weapons

Simple but powerful flippers and spinning discs are devastating, able to topple foes and tear through thick armour.



### Complexity

Complex robots may have a spectrum of different uses, but the more moving parts a robot has, the more likely it is to break!



### Intelligence

To program your bot with a degree of artificial intelligence you'll need sophisticated software and a powerful CPU.

*"It's now easier and cheaper to construct our own robots than ever before"*

### ADVERTORIAL

## Meet M.A.X.

Unlike anything else Meccano has created, M.A.X. combines artificial intelligence (AI) with customisable programming. The result is a one-of-a-kind robot of your own creation!

Budding engineers, and innovators can expand their knowledge of programming as they personalise this robot to their very own specifications. Once built, M.A.X. measures 30 centimetres tall. You can control it using voice commands, buttons on the MeccaBrain or the free Meccano Hub app. And you'll know exactly what it's thinking based on its expressive facial graphics.

Not just a learning tool, this robot loves fun. Try playing on M.A.X.'s built-in gaming platform, test your knowledge in a trivia game or listen to some funny jokes! With a multitude of features, kids will want to bring their new friend everywhere. This robot comes with built-in infrared sensors, enabling it to move with agility and avoid obstacles in its path. If you know a young mind in need of a challenge, introduce them to their new friend M.A.X.



M.A.X. is designed to engage and challenge young minds, using their knowledge of science, technology, engineering and mathematics

© Thinkstock; Meccano; Max Lifestyle; Nova



# BUILD YOUR OWN ROBOT

New from Haynes, this manual explores the tech behind the battle bots of BBC's *Robot Wars* and provides step-by-step guides for building your own

## Let's build a bug bot

Create an autonomous bug bot that can navigate around obstacles thanks to its own clever design

Find more designs, tips and tricks in *Build Your Own Robot* from Haynes



### You will need...

- 1** 1 piece of cardboard (approx 175mm x 150mm x 3mm)
- 2** 4x AA batteries
- 3** A rocker switch
- 4** A battery pack
- 5** 100mm of black wire
- 6** 400mm of red wire
- 7** 3D-printable Bug Bot body, or 2x sheets of coloured card
- 8** 2x plastic wheels
- 9** 2x geared motors

### Plus...

- A soldering iron and solder
- A hot-melt glue gun and glue
- Wire strippers
- Scissors
- Double-sided tape
- 2x micro switches
- A marker pen
- A sheet of A4 paper
- 2x elastic bands (30mm)
- 2x cable ties (203mm long, 4.5mm wide)



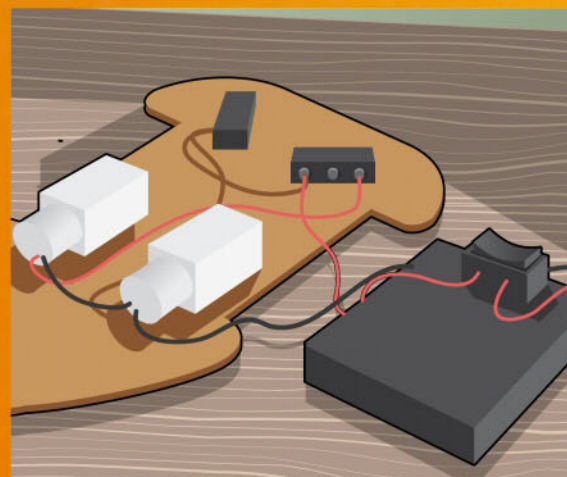
### 1 Create a platform

Using the accompanying image as a guide, start by drawing the platform shape on a sheet of A4 paper. Aim to make this template roughly nine centimetres wide at its widest point and 13 centimetres long at its longest. Once this is done, carefully cut out your paper template and place it on top of a piece of cardboard. Next, trace around the template with a marker pen and cut out the cardboard platform.



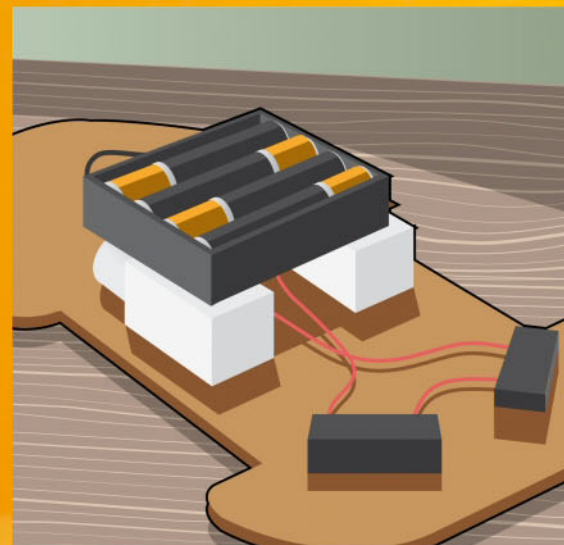
### 2 Arrange the components

Begin this step by carefully using your glue gun to attach the rocker switch to the underside of the battery pack. Now it's time to arrange our components on the paper template. Place the two drive motors at the narrowest point on the sheet and place the battery pack to one side. Above the motors, at the flat edge of the template, place the two micro switches, angled inward so that they're slightly facing towards the centre.



### 3 Connect your wires

Attach the red wire on the battery pack (with the switch attached) to one of the tabs on the rocker switch, then connect the two inner tabs of the micro switches using 50 millimetres of red wire. Next, attach the following with 120 millimetres of red wire: the outer tab on the left micro switch to the bottom tab of the right motor; the outer tab on the right micro switch to the bottom tab of the left motor; the inner tab of the right micro switch to the other tab on the rocker switch. To finish, solder the left-hand motor's top tab to the negative side of the battery pack and connect the top tabs on the motors using 60 millimetres of black wire.

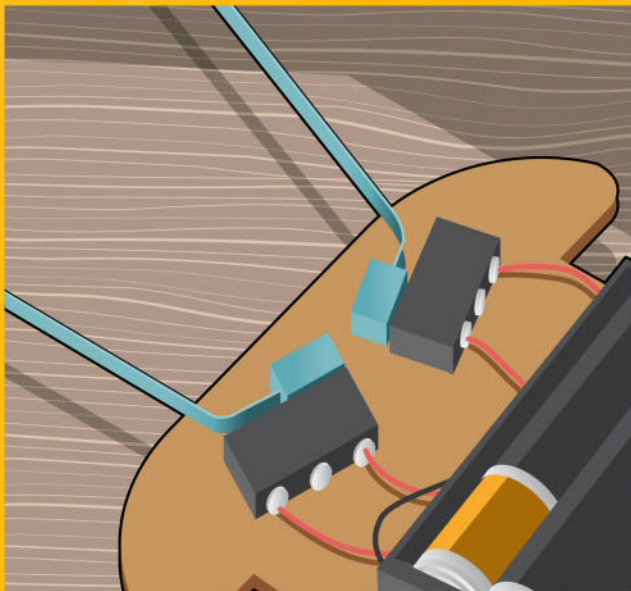


### 4 Bind your components

Add four AA batteries to your battery pack and test the motors before continuing, because you're now ready to start assembling your robot! Using the double-sided sticky tape, attach the two drive motors to the cardboard platform, making sure that they line up nicely along the narrowest segment. Stick the two micro switches to the card in the same positions as described in step 2 and finish by sticking the battery pack to the top of the motors.

### How to solder

The best way to ensure that you get an optimal connection between your wires and components is to use a pre-heated soldering iron and the 'tinning' method. This involves first soldering the two objects separately, waiting until the solder has cooled before bringing them together and then heating the solder with the iron, which will fuse the 'tinned' ends together and give you a strong connection.



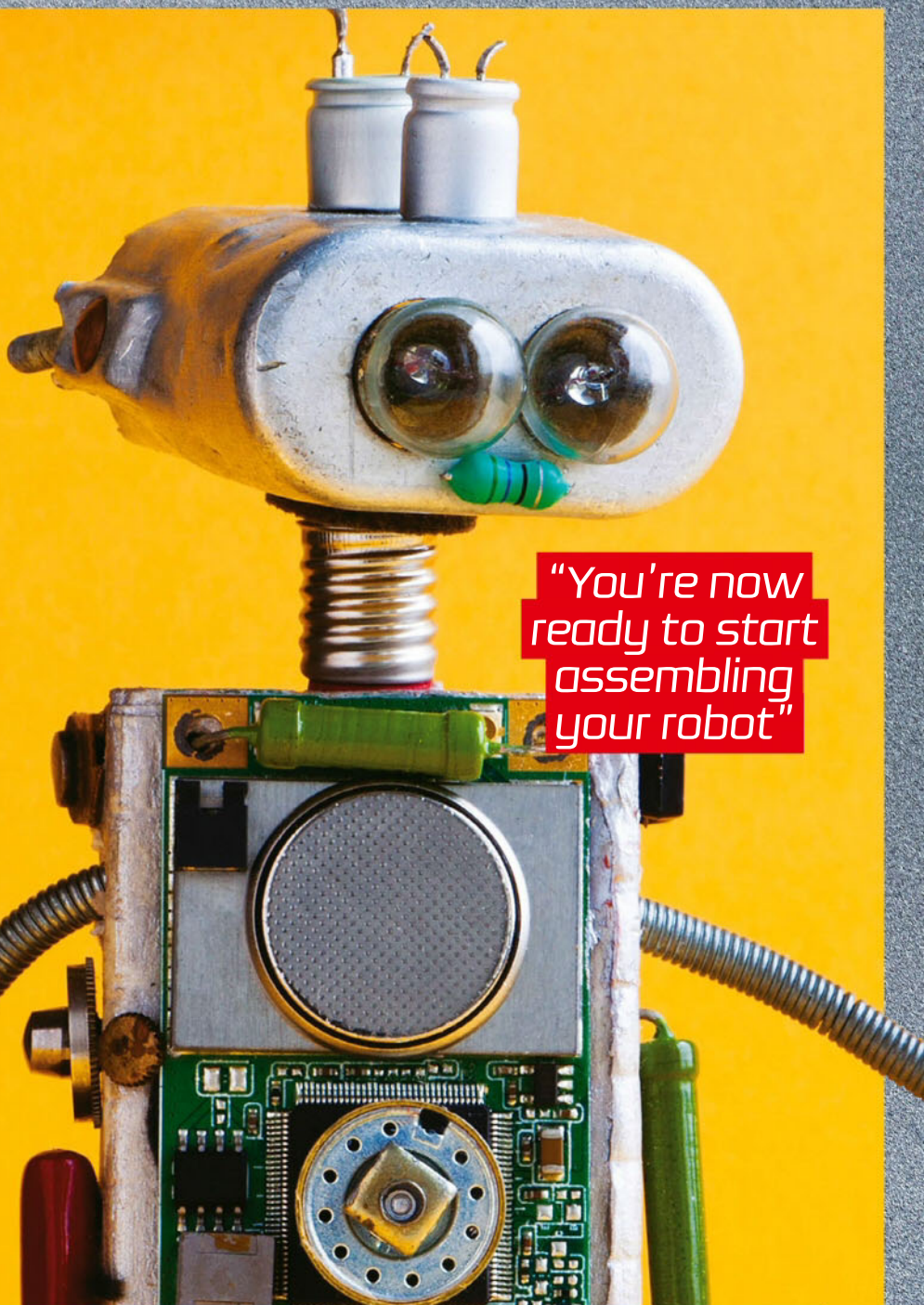
### 5 Add the antennas

Now you're going to create the bug's most iconic features — the antennas! Fetch your cable ties and make a 45-degree bend about 1.5 centimetres away from the square ratchet end. At the other end make another 45-degree bend but this time in the opposite direction. Your cable tie should look like a stretched 'S' when you're done. Next, using your glue gun, glue the ratchet ends to the micro switches.



### 6 Complete your bot

Gather your plastic wheels, double-sided sticky tape and two elastic bands. Cut thin strips of the sticky tape and wrap them around the wheels. Carefully stretch the elastic bands onto the tape — this will give the wheels more grip! Secure the wheels to the motors when you're done. Finally, your bug is going to need an exoskeleton. If you have access to a 3D printer you can download a design from [www.robotwars.tv](http://www.robotwars.tv). But if not, you can fold coloured paper or card for a simpler design.



**"You're now ready to start assembling your robot"**

### Top safety tips



#### **Wear appropriate gear**

It's recommended that you wear an apron to protect your clothes against any mess, but note that certain tools will require extra protection.



#### **Don't work by yourself**

Always make sure someone is close by to lend you a hand if needed, especially when you are using a new tool or technique for the first time.



#### **Avoid moving parts**

As you grow more experienced your machines will become more powerful. Make sure to keep your fingers clear of any moving parts while the robot is active.



#### **Be patient**

Most accidents happen when users are in a rush. Take your time when using potentially dangerous pieces of equipment. Follow any instructions carefully.



#### **Cool your tools**

Make sure you switch off your soldering iron and glue gun as soon as you have finished using them, and give them plenty of time to cool down properly.

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# Canary security system

Find out how this smart connected camera can help catch intruders in the act

**S**ecurity cameras are a great tool in protecting your home, but what if they could play a more active role in detecting and deterring crime? Rather than just watch the perpetrators, the Canary 'all-in-one' home security device notifies the user once it detects unusual activity in their home and can stream the footage straight to their smartphone.

The app allows the owner to view real-time footage from the Canary device to simply check the house or maybe to see what the dog's doing. The security settings on the app are activated whenever the device detects someone in the house and automatically alerts the owner. With the use of passive infrared motion sensors, Canary detects changes in heat energy that naturally radiate from a human body. The sensors then activate the built-in camera, which begins recording. Canary then gives the user the option to either sound a siren or call the police.

However, the original Canary model doesn't come without its limitations as it is unable to detect movement through window glass and cannot be placed outside. To combat this limitation the company has developed a weatherproof device, the Canary Flex, to brave the elements. This can be used completely independently of other Canary devices or be paired with the master Canary device for complete home coverage.

*"When Canary detects someone in the house it automatically alerts the owner via the app"*

Looking more like a Wi-Fi hub than a security camera, the Canary is sleek and inconspicuous

## HomeHealth Technology™

The Canary also monitors the temperature, humidity and air quality of the room it is in.

## Half-pint tech

What features make up such a compact security system?

### Camera

Captures video with a 1080p HD camera and a 147-degree wide-angle lens.

### Wi-Fi antenna

The device can interact with the app via a Wi-Fi or ethernet connection.

### Siren

Canary can emit a 90-decibel siren to deter intruders.

### Audio

The built-in speaker enables users to have real-time conversations with those at home via the app.

### Sensors

Motion sensors detect movement and automatically begin recording video.

### Size

Around the same size as a half-pint glass, the Canary is 15.2cm tall and weighs just 396g.

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# Time-lapse photography

Discover the ways to watch the world go by in a flash

**B**y taking a series of photographs in defined intervals, time-lapse photography speeds up time so you can see an entire day pass by in a video of only a few seconds; essentially the opposite of slow-motion.

The general rule for this technique is the faster the scene is moving, the shorter the intervals between each image and visa versa. To determine the length of the final clip a little maths is needed. In order to produce a video clip of one minute with image intervals of three seconds at 25 frames per second, you would need to take 1,500 pictures over a period of one hour and fifteen minutes. Automated 'intervalometers' snap a new image at the set interval, meaning you don't have to stand there clicking every couple of seconds.

## Speed it up

The frame rate can be varied to almost any degree using time-lapse photography techniques

### Camera

In order to achieve a time-lapse, the frame rate (frames per second) of the recorded scene must be lower than the frame rate used to play back the sequence.

Camera (6 frames per second)



Projector (24 frames per second)



1 second

### Playback

Recording a scene at six frames per second and playing it back at 24 frames per second would quadruple the speed of the video.

*"See an entire day pass by in a video of only a few seconds"*

## Barefoot shoe technology

Meet the minimalist footwear providing maximum flexibility

## Barefoot shoes

How advanced footwear can help us go back to basics

**H**umans didn't evolve to have to wear shoes; they change the way we walk. We have adapted to an unnatural walking position as a consequence of wearing over-supported, thick, cushioned shoes. As a result our feet have become lazy and weak. Barefoot shoes take us back to basics by allowing our toes to spread naturally in lightweight, flexible shoes, providing greater stability and grip and encouraging skilful movement.

It is hoped that by providing less structural support to the ankle and arches it may be possible to strengthen the muscles in the foot. This would allow 200,000 nerves in each foot to feel the terrain and provide your brain with this sensory feedback, keeping you from stepping into trouble. Here we meet the clever shoes allowing your feet to reconnect with the ground.

### Breathable fabric

Lightweight, breathable fabric keeps the shoes cool and flexible, so the wearer can move their feet completely freely.

### Individual toes

Wrapping each digit individually allows wearers to spread their toes for more natural foot movement.

### Pods

Anatomical 'pods' help to distribute the impact on the forefoot.

### Thin rubber

A puncture-proof layer of thin rubber helps to protect against dirt and debris and makes walking on hard surfaces more comfortable.

### Tread

Rubber treads help to provide strong grip on a variety of terrain and in a range of different weather conditions.





# Class of the TITANS

Meet some of the largest dinosaurs to have ever roamed prehistoric Earth

In an era where humans dominate the land, it is rare for us to encounter animals bigger than ourselves in our daily lives. However, if we had existed during the Cretaceous period, Sauropods would have had us running for the hills. One particular giant has been hitting the headlines this year after finally getting a name. Discovered in 2012, the *Patagotitan mayorum* was a plant-eating, long-necked, stomping giant that weighed more than 11 African elephants: it is among the largest animals to have ever walked the Earth.

The unearthing of this giant began at the La Flecha farm in Patagonia, Argentina, when a ranch worker named Aurelio Hernández came across one of over 200 fossils of this gigantic Titanosaur. The specimens collected from the site are believed to have come from at least six individual patagotitans to form the most complete anatomical reconstruction of a Sauropod to date.

## DISCOVERING A GIANT

As the heavyweight champion of the Titanosaurs, the patagotitan weighed in at around 69 tons, making the largest nine-ton *Tyrannosaurus rex* look minuscule. Stretching out from head to tail, this titan measures around 37 metres, the same length as around eight London taxis lined up next to each other.

Determining the weight of the patagotitan is difficult, with multiple methods being used among palaeontologists. Lead palaeontologist Dr Diego Pol and his team used two methods to calculate the patagotitan's body mass. The first method used an equation requiring the circumferences of the main limbs that supported its body, the femur and humerus, to estimate the weight they could support. An alternative method was to 3D scan each of the fossils to form a complete reconstruction of the patagotitan and estimate the volume of the surrounding soft tissue. Researchers believe that these fossilised

*"Stretching out from head to tail, this titan measures around 37 metres"*

## Movement

These massive, slow-moving giants put most of their energy into eating to stay alive, but it was also more difficult to move with their larger limbs.

## Titanosaurs

Discover some of the characteristics that make up these giant dinos

### Diet

As herbivores, these dinosaurs had molar-shaped teeth to grind and chew an enormous amount of food.

### Long neck

Large, elongated necks enabled these dinosaurs to eat vegetation beyond the reach of their smaller rivals.

### Tail

Tendons connected the tail and the thighs of the back legs, helping to lift the legs when the dinosaur walked.



A patagotitan reconstruction is exhibited in the American Museum of Natural History, where it takes up two rooms.

remains are possibly from a specimen that is not fully grown, so maybe there are bigger dinosaurs to unearth.

However, it's not just the size and mass of a patagotitan that the fossil specimen can show us: it also reveals some of its behaviours and movements. Examining the teeth of dinosaurs can indicate their diet; a mouth full of grinding molars indicates a vegetarian diet, like the patagotitan and other Sauropods.

In the case of the patagotitan, the archaeological team found three levels of specimens in the same location on a floodplain, where the dinosaur's remains were covered over time by sediment brought over by the flooding

water. This occurred at least three times at this site, indicating that the prehistoric giants had visited this site on at least three separate occasions. Much like we see in elephants, some of the fossil specimens of the patagotitan even had marks suggesting living patagotitans had stepped on them. It has been speculated that due to periods of drought, these beasts may have died from dehydration by becoming entrapped in the surrounding mud.

### A GARGANTUAN GROUP

Dominating the land when the first examples of flowering plants began to bloom, these behemoths walked among giants. Patagotitan

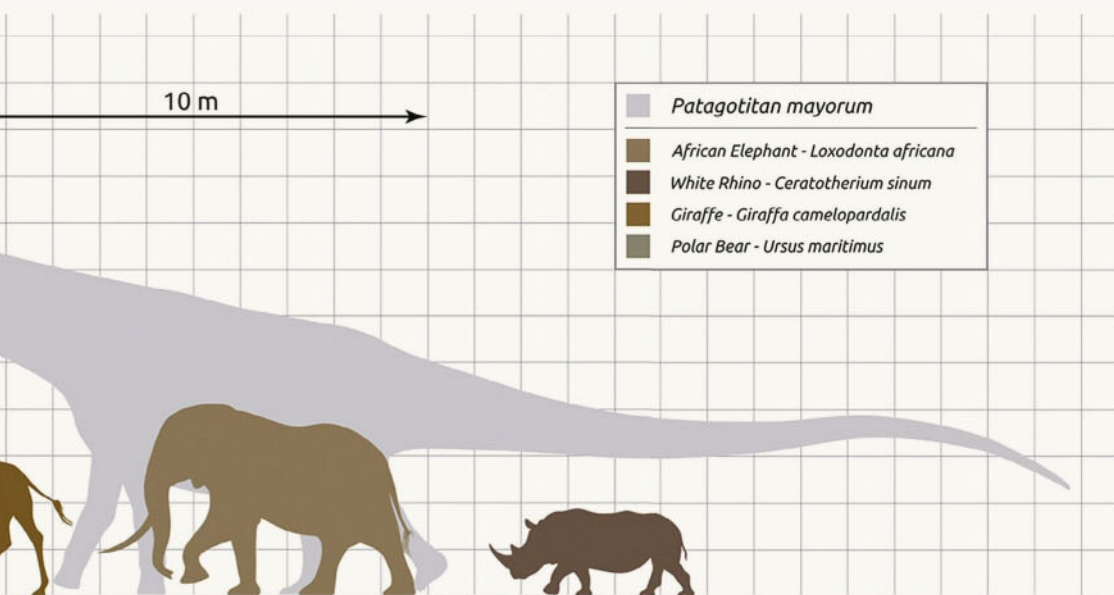
The patagotitan makes some of the largest animals currently in existence look tiny

Evidence of Titanosaur fossils have been found across nearly every continent



fossils have been dated back to around 100 million years ago, but they're not the only example of giant dinosaurs; this class of the titans includes multiple examples of towering dinosaurs. Even the smallest of the Sauropods, the Saltasaurus, weighed in at around seven tons.

Previously believed to have been the largest of the group, the argentinosauros is estimated to have weighed around 70 tons. There is a limited amount of fossil evidence to completely reconstruct a argentinosauros, so the patagotitan is thought to be the largest animal ever due to the greater number of preserved anatomical fossils found.



Patagotitan had an estimated length of

**37m**



Equivalent to **8** London taxis bumper to bumper

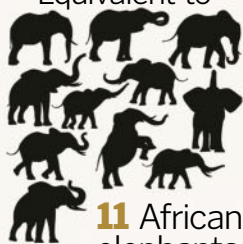
The longest blue whale was only

**32m**

Patagotitan had an estimated weight of

**69 tons**

Equivalent to



**11** African elephants

Almost as much as the Space Shuttle Endeavour



**75 tons**

## THE FAMILY NAME

Placing species on the 'tree of life' takes time — four years in the case of the *Patagotitan mayorum*. Previously generalised simply as the Titanosaur, the dinosaur's new name pays tribute to the location of its discovery (Patagonia) and the Greek word for large ('titan'). The name 'mayorum', however, honours the name of the

*"Patagotitan fossils have been dated back to around 100 million years ago"*

family that hosted the researchers during their long excavation.

To formally classify a new species with a new name, its lineage must first be identified. Often called the 'tree of life', every known species on Earth filters into different classifications. Using data collected from fossilised remains, palaeontologists can link a species to its prehistoric lineage and determine who's related to whom. The Titanosauria is a diverse clade (group of evolutionary descendants of a common ancestor) of Sauropod dinosaurs that includes some of the largest known land animals to have ever graced the planet.

## An expert opinion

Dean Lomax is a multi award-winning palaeontologist, science communicator, TV presenter and author of *Dinosaurs of the British Isles*



### How important is this discovery for the field of palaeontology?

Every new fossil find is important as it helps to add a tiny piece to a gigantic prehistoric jigsaw puzzle. The

discovery of [the] patagotitan is important in furthering our knowledge of gigantic dinosaurs and the diversity of the group (Titanosauria) it belongs to. The patagotitan is one of the most complete giant dinosaurs known, which helps to 'fill in' the missing pieces of what was previously unknown in other giant Titanosaurs.

### For such a huge giant, how much did it need to eat?

In order to maintain its huge size — [around] 70 tons — the patagotitan would need to have been eating constantly. Of course, it's difficult to put any accurate estimate for the amount of vegetation required, but it would certainly have been a huge amount.

### What can the evidence of multiple patagotitans tell us?

At least six individual patagotitan specimens were found in the same quarry, although some were found at slightly higher levels, and it is thought that they perished in three different burial events. Clearly it shows that some of these individuals of different size must have been living together in herds.

### Why is the name of a new dinosaur species so important?

This is the foundation of palaeontology. The fossil record is very incomplete, especially when we consider that only a tiny percentage of all animals that once lived on the planet have been found as fossils. So describing new species and working out where they fit on the tree of life is important in understanding their place in the history of life in deep time.



# Trick or Trojan

Did the Greeks really win the war with a wooden horse?

After a ten-year siege, Greek soldiers seized the city of Troy by hiding inside a hollow wooden horse masquerading as a peace offering. The Trojans victoriously dragged the horse inside the city walls and consequently sealed their fate. Or so the story goes.

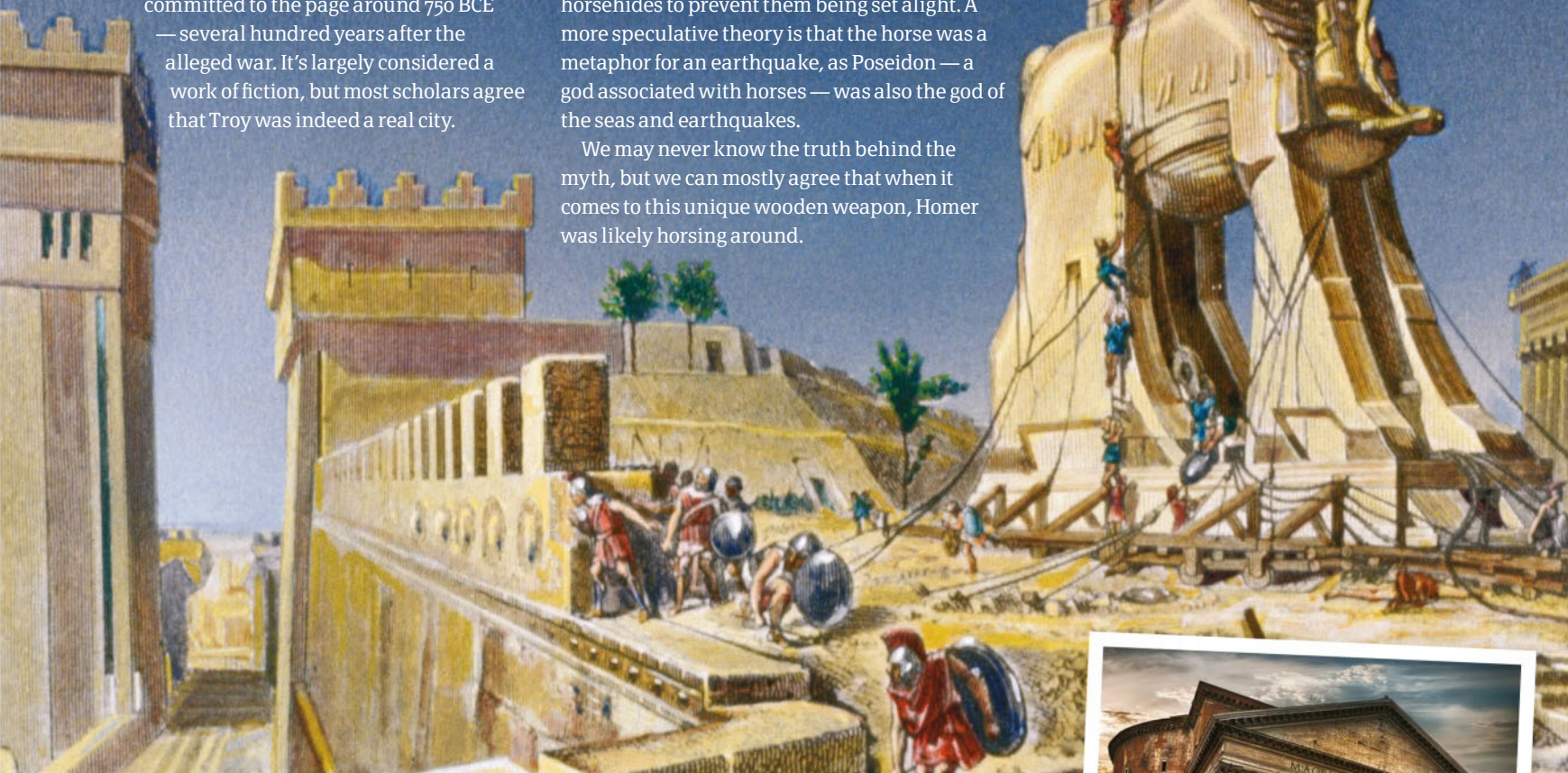
The earliest recorded mention of the Trojan horse was in Homer's *Odyssey*, an epic that was committed to the page around 750 BCE — several hundred years after the alleged war. It's largely considered a work of fiction, but most scholars agree that Troy was indeed a real city.

Believed to be in modern-day Hisarlik in southern Turkey, there's even archaeological evidence suggesting that it was burned down.

The horse, however, is complete fiction. Modern historians suggest it could have been inspired by ancient siege engines — wooden battering rams used to break down city walls. Attackers would cover them with damp horsehides to prevent them being set alight. A more speculative theory is that the horse was a metaphor for an earthquake, as Poseidon — a god associated with horses — was also the god of the seas and earthquakes.

We may never know the truth behind the myth, but we can mostly agree that when it comes to this unique wooden weapon, Homer was likely horsing around.

The horse was the supposed symbol of the city of Troy



# Rome's secret super material

Scientists want to know why ancient structures are still going strong

It's been dubbed the most durable building material ever, and it was created thousands of years ago. Ancient Roman concrete was used to create iconic structures such as the Pantheon and the Colosseum, but it's the piers and sea walls that scientists are most interested in. Many of these marine marvels are still standing while modern concrete decays within decades.

Using a combination of high-powered X-rays, Raman spectroscopy and electron microscopy,

scientists from the University of Utah have uncovered the chemistry. The Romans used a mix of volcanic ash, quicklime (calcium oxide), chunks of volcanic rock and seawater, which triggers a chemical reaction. This reaction produces crystals that continue to grow over time, which strengthen the concrete and prevent cracks from developing.

Meanwhile, modern Portland cement uses sand and gravel particles as they are intended to

be chemically unreactive. This means that any reactions that occur can expand and crack the concrete. The process is also responsible for approximately five per cent of global carbon dioxide emissions.

It is hoped that by figuring out the Roman's exact formula we could in future replace modern concrete with a stronger, more environmentally friendly material that will truly stand the test of time in the way the Roman's concrete has.



The Pantheon and Colosseum were built using Roman concrete and are still standing after approximately 2,000 years

# History of the British Library

This centuries-old institution holds one of the most extensive collections of global knowledge

**A**lthough the modern British Library was established as recently as 1973, its origins stretch back as far as the 18th century. Its original collection was bequeathed to the nation for the sum of £20,000 by Sir Hans Sloane, a physician who had collected over 71,000 artefacts including manuscripts, books and coins during his lifetime. His collection was opened in 1753 in Montagu House, Bloomsbury as part of the British Museum Library, the present site of the British Museum.

In 1662 the statute of Legal Deposit was passed in England and Wales, requiring a copy of every printed publication to be given to the British Museum Library (and five other legal deposit libraries in the UK). In 1710 this statute was extended to include the whole of the UK.

In May 1857 the iconic Reading Room was opened, allowing members of the public access to the library's treasures. However, passes were soon introduced, admitting only approved members.

In the latter part of the 19th century the library's full catalogue had reached its 2,250th

volume, each one of them handwritten. This was transferred into 437 printed parts over the course of around 25 years. By this time the full collection counted some 2 million printed titles.

In its new location on Euston Road, the modern British Library now houses items in most known languages and continues to house and collect not only all print material produced in the UK and Ireland but also a wide range of music and film recordings.

Many famous writers and politicians studied in the British Museum's Reading Room, including Karl Marx, Vladimir Lenin and Sir Arthur Conan Doyle

The current British Library was opened by HRH Queen Elizabeth II in June 1998



Over 400,000 people use the library's reading rooms each year



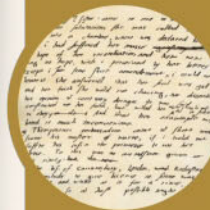
## Written treasures

Discover some of the library's most valuable tomes



### The world's oldest book

The British Library is home to the only known copy of the *Diamond Sutra*, a Buddhist scroll made in 868, making it the world's earliest-dated printed book.



### A right royal read

The *Cotton Manuscripts* contain signed letters by Henry VIII and Elizabeth I, the personal diary of Edward VI and the last will and testament of Mary Queen of Scots.



### Da Vinci's codex

Over 7,000 pages of Leonardo da Vinci's notes and drawings (including his theories and inventions) have survived and now form part of the manuscript collection within the British Library.



### Captain Scott's diary

The Terra Nova Expedition (1910-13) included Captain Scott's team's attempt to reach the South Pole. They recorded their experience in his diary, which enabled their story to be told to a nation.



### English heritage

*Beowulf*, regarded as the greatest poem in Old English, Shakespeare's *The First Folio* and two of four surviving copies of the Magna Carta 1215 are all housed at the British Library.

# 150,000,000+

The number of items currently held by the British Library

# 3,000,000 625

new items are added to the library's collection every year

If you saw five items each day it would take

# 80,000 years

to view the library's entire collection

# 225,000

Volumes lost during a German air raid in 1941

# 625 KM

The distance covered by all the library's shelves and growing every year

## Ticket to Ride Europe

**Build a network of trains across early 20th-century Europe**

■ Publisher: Days of Wonder ■ Price: £38.99 (approx. \$50) ■ Number of players: 2-5 ■ Ages: 8+ ■ Typical game time: 30-60 mins

In *Ticket to Ride Europe* the aim of the game for players is to collect and play train cards in order to place your pieces on the board, with the goal to connect cities on your ticket cards. For filling out these train cards you then get all-important points, which decide the winner at the end of the game.

The board and instruction manual may look complex, bordering on bewildering at first, but don't worry, you'll quickly get your bearings — figuratively and literally — as the gameplay is very straightforward. Taking turns to play your

train cards and connect your cities to make complete routes throughout Europe, this is a fast-paced game to play and welcomes players of different generations to play each other, as luck of the draw can often play as big a part as the strategic playing of cards.

There are some twists in play, such as higher costs for placing pieces on tunnels and the requirement for special locomotives to use ferries, as well as trading in some of your points to use other players' routes to connect your own, but otherwise the gameplay is quite simple. Not

only that, but playing the game also educates all players on the cities and train routes of early 20th-century Europe, especially opening up a world of discovery in Eastern Europe and Russia. While you can play with just two players, we recommend at least four players are involved for the best experience.

### Only connect

How to dominate the train tracks of pre-war Europe

#### Connecting cities

Train travel was the main mode of transport at this time, so good connections between cities were vital. It's also your goal here.

#### All aboard

You have to play these to lay down your routes throughout Europe.

#### Present your ticket

These cards tell you the cities you need to connect, giving you a simple but exciting goal for your final destination.

#### Keeping score

This handy scoring card is your quick-reference guide to how many points you can collect for your routes.

#### Do the locomotion

For some routes, such as when using ferries, you'll need a special locomotive card.

#### Far-flung destinations

The game will introduce you to often under-explored parts of Europe, such as Russia and Eastern Europe.

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# BRAIN DUMP



Because enquiring minds need to know...

## MEET THE EXPERTS

Who's answering your questions this month?

### Laura Mears



Laura studied biomedical science at King's College London and has a master's from Cambridge. She

escaped the lab to pursue a career in science communication and also develops educational video games.

### Alexandra Franklin-Cheung



Having earned degrees from the University of Nottingham and Imperial College London, Alex has

worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

### Tom Lean



Tom is a historian of science at the British Library where he works on oral history projects. He published his first

book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer*, in 2016.

### Katy Sheen



Katy studied genetics at university and is a former **How It Works** team member. She now works for a

biomedical journal, where she enjoys learning about the brilliant and bizarre science of the human body.

### Joanna Stass



Having been a writer and editor for a number of years, **How It Works** alumnus Jo has picked up plenty of fascinating facts.

She is particularly interested in natural world wonders, innovations in technology and adorable animals.

## Want answers?

Send your questions to...

f How It Works magazine @HowItWorksmag

@ howitworks@futurenet.com

UK weather forecasters struggle because the jet stream's movements are difficult to predict



## Why is weather in the UK so changeable?

### Ash Hussein

■ The unpredictability of the UK's weather is caused by its location on Earth and the Earth's rotation. The UK is situated directly beneath the boundary between two of the Earth's climate cells: the cold polar air to the north and the warm tropical air to the south. These two types of air are constantly battling against each other,

with the winner of the battle being decided by the jet stream, a fast wind blowing ten kilometres above us that is a product of the Earth's spin. It coils around the planet at about the UK's latitude, causing the climate cell boundary to move and bring either colder or warmer air across the country. This constant shift in boundary lines explains our varying weather. **JS**

## How do you split an atom?

### David Cartwright

■ Some unstable nuclei can split spontaneously, but this is very rare. Heavy atoms can be induced to split by bombarding them with neutrons, a process known as nuclear fission. The easiest atoms to split are large radioactive isotopes such as uranium-235. When a uranium-235 atom absorbs a neutron, the uranium nucleus becomes highly unstable and splits into two smaller nuclei and three neutrons. These free neutrons can break apart other uranium-235 atoms, resulting in a chain reaction. **AC**





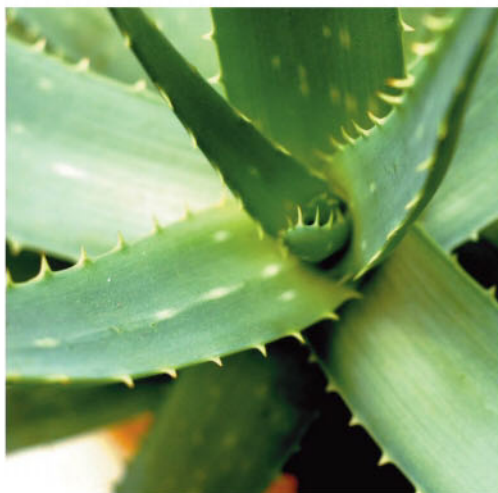
These incredibly resilient reptiles appear to be built for survival

## How did crocodiles survive the dinosaur extinction?

Hettie Lawes

It isn't clear why crocodiles and alligators survived this mass extinction event while larger reptiles like dinosaurs were wiped out. However, crocodiles are tough creatures — in territorial fights they are known to lose limbs and suffer

serious injuries, but they often survive. They can also withstand long periods of starvation and maintain a low body temperature. As water-dwelling reptiles, crocodiles may have had the advantage of taking to rivers, lakes or swamps to avoid danger on land. **KS**



## Does aloe vera help soothe sunburn?

Ben Jones

Aloe vera has been used to treat burns for thousands of years and is found in after-sun lotions, but there's actually little scientific evidence to prove that it soothes sunburn. Although some studies have found that it contains anti-inflammatory compounds and may even accelerate the healing process, very few studies have directly evaluated these effects on humans. Instead, it could be the cooling feeling of the liquid evaporating from the skin or additional ingredients in after-sun lotions that help to reduce the pain. **JS**

## What do gears on a bike do?

Cody Prescott

Shifting gears on a bike changes the speed or force generated by each pedal stroke, making it easier for cyclists to go up steep hills with minimal force or pick up as much speed as possible. When you pedal you turn the sprocket, which is connected by the chain to the rear sprocket, spinning the back wheel and allowing you to move forwards. In a high gear, a full rotation of the pedals is translated into several times as many rotations of the back wheel, generating speed. In a low gear, the change in gear ratio allows pedalling to generate fewer rotations (and less speed) but more force. **AC**



## What does a graphics card do?

It transforms binary data from the computer's central processing unit (CPU) into instructions for using the pixel (tiny dots) to create a 2D or 3D image on your computer's monitor. **AC**



## Which is the oldest university in the world?

The University of Al Qarawiyyin in Morocco was founded in 859 by Fatima al-Fihri, making it the world's oldest continuously operating educational institution. **AC**



## What is the fastest commercial plane?

The fastest currently in use is the Boeing 747-8 Intercontinental, which can reach speeds of Mach\* 0.86 or 913.32 kilometres per hour, but the fastest ever was Concorde, with a cruising speed of Mach 2.02 (2,145.24 kilometres per hour). **JS**

\*Mach speeds are dependent on the altitude of the aircraft. These speeds are calculated using the cruising speed at 12,192 metres.



## What is the smallest country in the world?

In terms of landmass, Vatican City is the smallest country in the world. It has an area of 0.44 square kilometres, making it less than half the size of London's Hyde Park. **KS**





Iodine is an antiseptic used to clean the skin before surgery

## What is the difference between antiseptics and antibiotics?

**Chelsea Barker**

■ Antiseptics and antibiotics are both forms of antimicrobials, which are compounds that kill microbes such as bacteria, fungi and other pathogens. Antiseptics like iodine and rubbing alcohol are applied externally in order to kill microbes and stop their growth. However,

antibiotics are absorbed or ingested as a cream, tablet or injection to treat infections inside the body. While some antiseptics can inactivate viruses and kill fungi, antibiotics will only work against bacteria, leaving infections like the common cold, flu or athlete's foot completely unaffected. **LM**



Photochromic lenses can darken within one minute of stepping outside

## How do light-sensitive glasses work exactly?

**Toby Benson**

■ Light-sensitive glasses are made with photochromic lenses, which allow them to appear like clear glasses indoors and dark sunglasses outdoors. Normal sunglasses work by filtering out certain wavelengths of light, so everything appears darker. Photochromic lenses are able to adjust how much light passes through, depending on how much UV light is hitting them. When you are outside, UV light from the Sun causes molecules in the lenses to change shape so that they can absorb more light. When you step inside, there is less UV light, so the molecules shift back to their original shape and more light passes through the lenses to your eyes. **KS**

## How fast is the Hyperloop prototype?

Hyperloop One aims to propel passenger pods along a vacuum-tube system at speeds of up to 1,220 kilometres per hour. In July 2017, a prototype reached 310 kilometres per hour at the test site in Nevada, US. **KS**



## What do the letters GIF stand for?

It stands for Graphics Interchange Format. It was invented in 1987 for transferring images over slow connections, storing the data in compressed 8-bit pixel format with up to 256 colours. **LM**



## How close do the Red Arrows get to each other during their flying displays?

Zippering through the sky at up to 966 kilometres per hour, the Hawk jets flown by the Red Arrows can be just 1.8 metres apart from each other as they perform aerobatic displays. **TL**



## Is there a speed limit on the Autobahn?

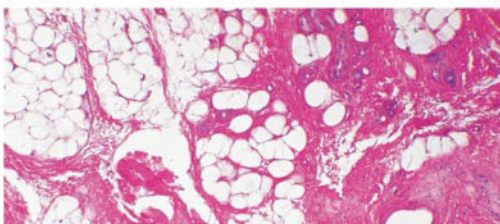
There are speed limits of 80-130 kilometres per hour on parts of the German Autobahn network. On the majority of Autobahns there are no speed limits for cars, but other vehicles, like buses, have restrictions on how fast they can drive. **TL**



## When did wolves become extinct in the UK?

Nish Patel

Centuries ago wolves hunted across the different countries that now make up the UK, but their numbers declined as humans hunted them to extinction and destroyed their habitats through deforestation and development. Officially, the last wolf in mainland Britain was shot dead in 1680 in Scotland. However, there are stories that wolves managed to survive in remote parts of Scotland for approximately another two centuries, and it wasn't until 1786 that the last recorded wolf in Ireland was killed. **TL**



## How long does it take excess calories to be stored as fat?

Lee Willis

Excess calories from carbohydrates are converted to and stored as a quick-access carbohydrate called glycogen in the liver and muscles. An adult can store 100 grams, so once storage is full any excess sugar is converted into fatty acids. If unused these become fat cells. **LM**



## How can countries censor their internet?

Gene Irman

Internet filters use two main mechanisms: blacklisting and keyword blocking. Blacklisting bans access to certain sites, while keyword blocking searches pages for certain words and prevents the sites appearing. Different countries use different tactics. China uses a firewall nicknamed 'The Great Firewall of China', which checks and blocks sites, while in Cuba private internet access is banned. In Myanmar the government allegedly monitors internet cafés by taking screenshots as you browse. **LM**



## Who invented the ballpoint pen?

Ryan Peterson

Hungarian journalist and artist László József Bíró invented the ballpoint pen in 1938 after noticing that newspaper ink dried quicker and smudged less (verses fountain pen ink) and eventually patented a new pen tip to easily distribute the thicker ink onto the page. **JS**



## What's the difference between the internet and the web?

Renee Peters

The world wide web is a way of using the internet, not the internet itself. The internet is a huge network of networks that connects computers around the world. The world wide web is an information system that runs on the internet and allows access to web pages through a browser. However, just like a road carries different sorts of traffic, the internet carries different sorts of data for other systems as well, such as email and file transfers. So there is far more to the internet than just the web. **TL**

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# BOOK REVIEWS

The latest releases for curious minds

## Star Wars: The Visual Encyclopedia

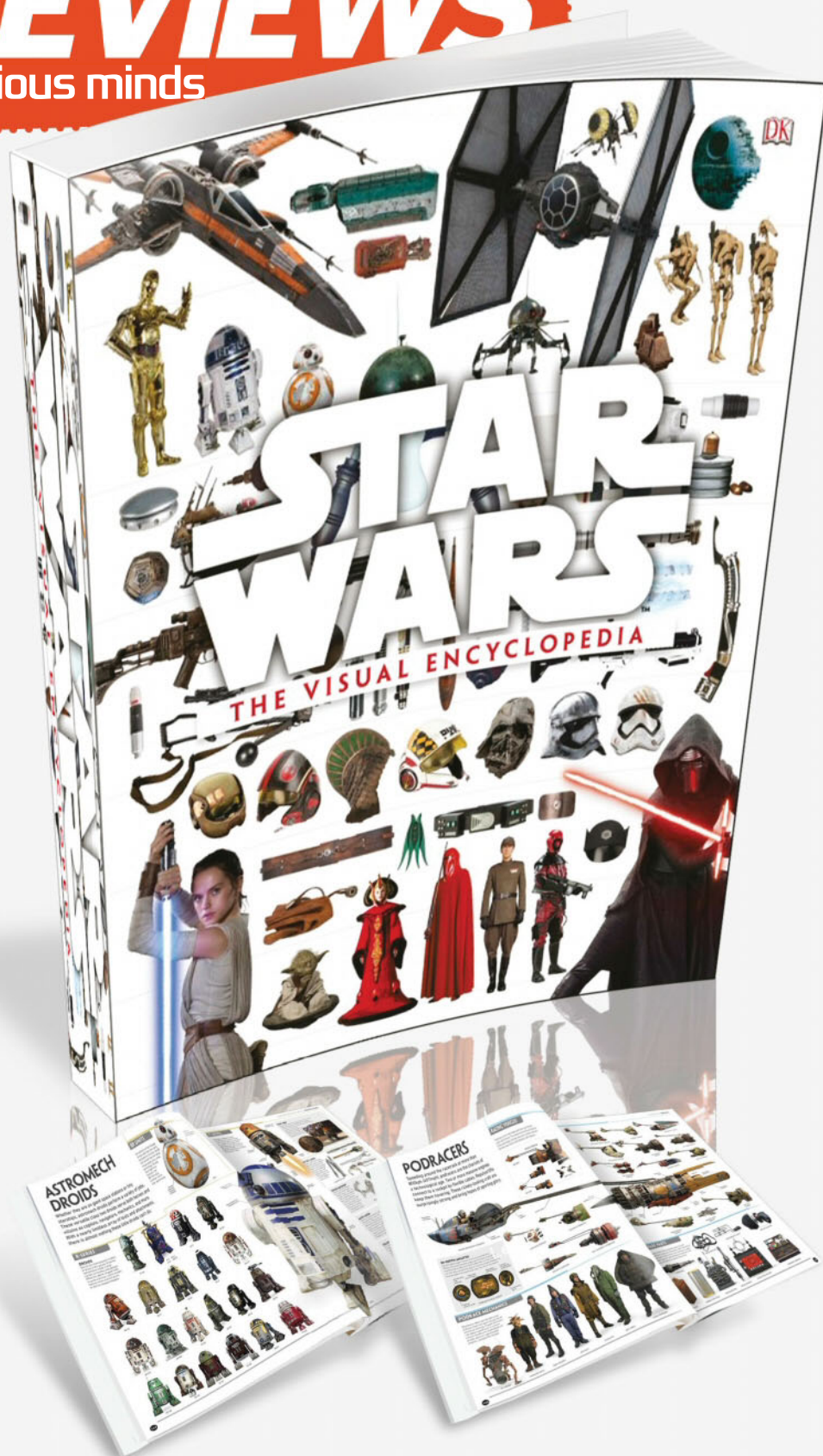
Learn incredible details about a galaxy far, far away

Author: **Tricia Barr, Adam Bray & Cole Horton**  
Publisher: **Dorling Kindersley**  
Price: **£25 / \$30**  
Release date: **Out now**

**H**ave you ever watched *Star Wars* and wondered about the history of Coruscant or wanted to know more about the aquatic creatures from across the galaxy? The movies and TV shows don't always have time to go into detail about the history, biology and geography of the series, meaning fans have to do their own research to find out more. But no more, thanks to this bulging book of facts.

This encyclopedia is absolutely packed with information about every imaginable part of the *Star Wars* universe. Want to know about the fresh foodstuffs that are eaten by the inhabitants of the galaxy or the bizarre musical instruments, technology or even luggage designs that are used? Well, this book tells you all about them — and a lot more besides.

The book includes information from every movie and the TV shows, right up to *Rogue One: A Star Wars Story*, meaning there's a lot of stuff to cover. Sadly, the book doesn't include any details from the upcoming movie, *Episode VIII: The Last Jedi*, although this is probably for the best for those that want to avoid spoilers. Thankfully, it doesn't have any noticeable effect inside, and there is still an astonishing amount of information packed into the book.



**"As huge Star Wars fans we found it hard to find any downsides to this book"**

We wonder whether DK will release an updated version of the book following the movie release, with new facts based on the new story. We'll keep our fingers crossed, but for now this will keep us extremely busy.

As huge *Star Wars* fans we found it hard to find any real downsides to this book. The only small issue we had was that certain entries contain a little less information than others, meaning you might still have questions when you turn the

page. However, these slightly lighter entries are fairly rare, and there are others throughout the book that are *so* detailed, with brilliantly annotated images, cool facts and information that you would never have even considered.

For fans of the series this will undoubtedly provide hours of entertainment — it's the perfect way to get clued up before the new movie comes out in December.

★★★★★

## The Planet Factory

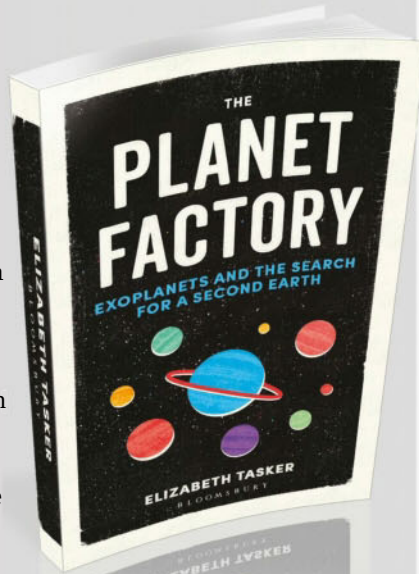
Brave new worlds

- Author: Elizabeth Tasker
- Publisher: Bloomsbury
- Price: £16.99 / \$27
- Release date: Out now

Are we alone in the universe? It's a question we continue to ask. For now, the answer is 'as far as we know', but with every new planet that is discovered, the expectation that the response might change grows slightly.

As little as we know about these exoplanets — worlds far outside our own Solar System — some of the findings that are detailed in this book suggest that they could be unlike anything we've ever heard of previously. Take the lava-filled inferno of 55 Cancri e, or the binary star system of VV Cephei. Maybe Tatooine's two suns weren't as far-fetched as we thought after all.

Essentially, *The Planet Factory* seems to be designed to remind us



of how much, and indeed, how little we know about the universe. It's clear that there's so much more out there, and it does a great job of filling in some of the many blanks in our knowledge. It may require some scientific background to get the most out of, but otherwise you're all set.



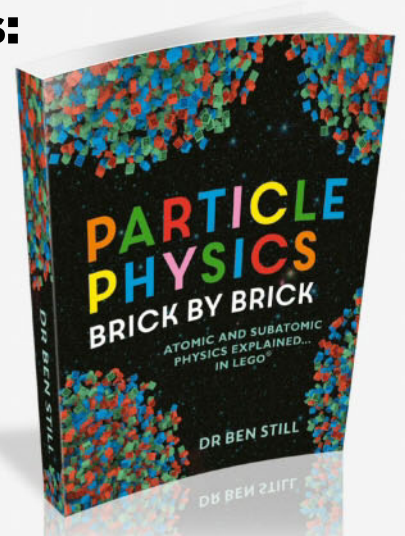
## Particle Physics: Brick by Brick

Lego of your physics phobias

- Author: Dr Ben Still
- Publisher: Octopus
- Price: £14.99 (approx. \$20)
- Release date: Out now

Lego makes everything easier to understand, it's a fact — ask any scientist or clever person you know. Which makes it very handy when it comes to the study of particle physics, a subject not exactly renowned for its accessibility.

Breaking everything down into perfectly manageable blocks (literally), *Particle Physics: Brick by Brick* attempts to concisely explain how different chemical elements are formed via the interaction of subatomic particles, in the process explaining various phenomena and live-changing particles. From the Big Bang Theory to the Higgs boson, a wide net is cast over the building blocks of the universe.



However, even with the aid of the wonderful world of Lego, this book may prove to be too tricky to understand for some — it turns out that even the brilliant building blocks have their limitations. And while author Dr Ben Still's aim is admirable, ultimately the inclusion of Lego in this book turns out to be a little bit of a gimmick that doesn't really add anything beyond an eye-catching sub-heading.



## RAF 100 1918-2018: Technical Innovations Manual

Flying high

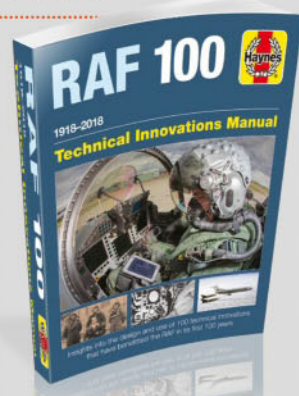
- Author: Jonathan Falconer
- Publisher: Haynes
- Price: £25 (approx. \$33)
- Release date: Out now

Whenever you pick up a Haynes manual you can rest assured that the content within it will be both rigorously researched and crazily compulsive, and once again it comes to pass here as the renowned publishers mark the 100th anniversary of the Royal Air Force (RAF).

As you would expect, plenty of space is devoted to the pivotal role the RAF played in defending Britain during World War Two, detailing the innovations and events that helped it turn the tide of history. However, this doesn't

dominate the book. From its establishment immediately post-1918 to relatively recent additions like Aircrew Equipment Assembly and FLIR (Forward Looking Infrared), the RAF's continued importance is underlined throughout.

Like pretty much every Haynes manual, your enjoyment levels will largely depend on your investment in the subject matter. If it's suitably high in the case of the RAF then you can consider this book a resounding success story.



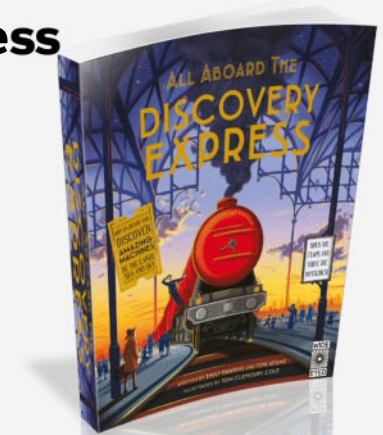
## All Aboard the Discovery Express

A journey through transport innovations

- Author: Emily Hawkins, Tom Adams
- Publisher: Quarto
- Price: £14.99 (approx. \$20)
- Release date: Out now

If you took on board one lesson from *Back To The Future: Part III*, it's that time-travelling trains are brilliant and we don't see nearly enough of them. Looking to rectify this, *All Aboard the Discovery Express* takes its reader on a locomotive-powered excursion through the time stream, calling in at some of the most pivotal turning points in transportation history.

Aimed primarily at younger readers, the book takes the form of an interactive adventure in which you must track a missing professor during your travels, making use of clues (often taking the form of



fold-out letters, diagrams etc) on the way, all the while being bombarded by waves of facts.

The focus is clearly more on presentation than perpetuating a relentless cavalcade of information — the text is minimal but put to good use — and this is an approach that works. If you're looking for a stocking filler for your budding Branson then look no further.



## The Element in the Room

Science made fun for adults (there's drinking and everything)

- Author: Helen Arney & Steve Mould
- Publisher: Cassell Illustrated
- Price: £16.99 / \$18.99
- Release date: Out now (US release March 2018)

Science can sometimes be dry, dull and even a bit boring — but we all know that it isn't always like that. In fact, there are tons of fun experiments that you can try to test out science in the world around you and plenty of ways that science can amaze and inspire. *The Element in the Room* proves this like few other books can.

Thanks to the witty and clever writing, every topic is engaging, fun and in some cases laugh-out-loud funny. The conversational tone is a real winner, with hilarious footnotes, smart references and amusing comments on every page that make this more than your average science book. Did you know that some scientists estimate that one in ten humans alive today were conceived in an Ikea bed? Amazing, right? The authors here joke about how many people have to sneak into Ikea at night in order to test the theory, and it's comments like this that make this as much comedy as it is science.

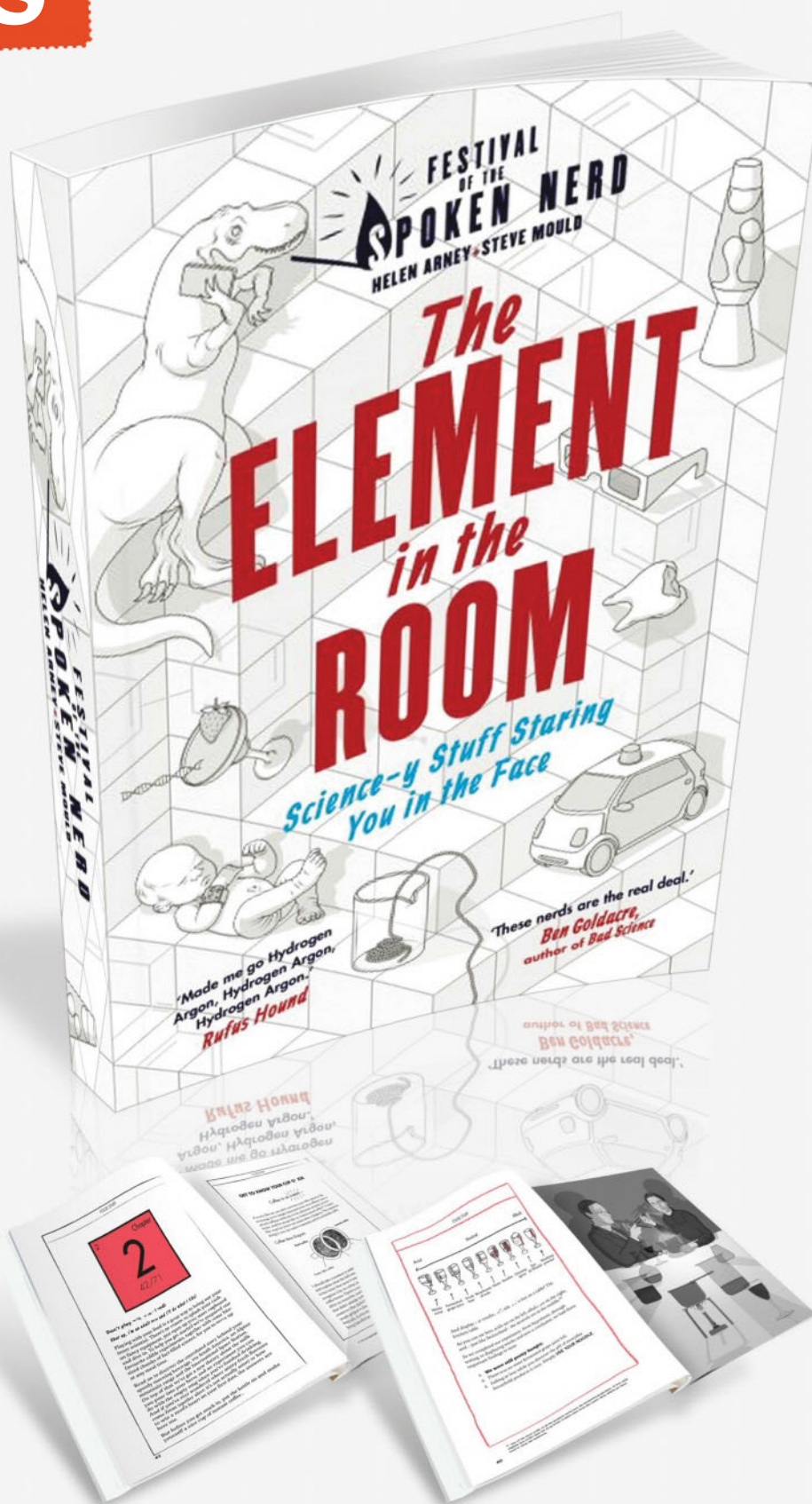
Then there are the experiments. The selection is exceptional — the book starts with simple experiments to find valves in the veins on your arms by pressing them with your fingers. By the halfway point you'll be creating spinning fire tornadoes in wastepaper bins, and by the end you'll be making alcoholic (and non-alcoholic) cocktails all in the name of science. This is certainly a book that aims its experiments at adults; the language is mostly suitable for younger ages, but the intended audience is definitely older.

There are too many highlights to mention. The Trip Advisor reviews of Earth-like planets around the Solar System are good fun, while the coffee Venn diagram will raise a smile (before going on to explain why instant coffee tastes so bad). The experiment to test the Leidenfrost Effect is cool (heating a frying pan to around 190 degrees Celsius and then watching water droplets dance), and comparing the amount of

radiation you experience through eating bananas is a highlight.

In case you can't tell, we loved this one. It's perfect for grown-ups who want to know more about science but also love having a laugh — and creating the odd fire tornado.

★★★★★



"By the halfway point you will be creating, fire tornadoes in waste paper bins"

## Do You Know About Space?

Discover the answers to your kids' cosmic questions

- Author: Sarah Cruddas
- Publisher: Dorling Kindersley
- Price: £12.99 (approx. \$17)
- Release date: Out now

In *Do You Know About Space*, author Sarah Cruddas brings to life our fascination with space and addresses this childhood curiosity with patience, insight and stunning visual imagery provided by NASA.

The book takes us on a guided tour through our Solar System and beyond, answering key questions including, 'Can you scream in space?', 'Where does space begin?' and 'How hot is the Sun?'

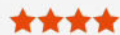
One highlight is Cruddas' response to 'How cold is space?', where she explores the extreme variance in temperatures between the Sun, Neptune and the Boomerang Nebula.

Generally, Cruddas' responses are simple yet thorough. The



diagrams and photographs aid our understanding and make the book easier to follow, especially for younger children. *Do You Know About Space?* is pitched at children aged six and up, but appears better suited to younger children due to the focus on illustrations.

Overall, the book is a stimulating and useful tool for anyone (child or adult) seeking answers about space.



## Why Dinosaurs Matter

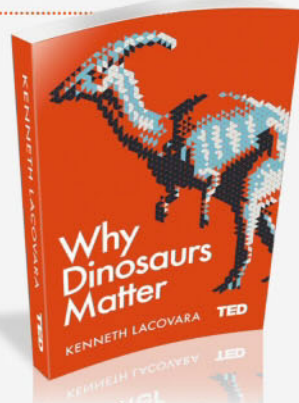
A big book in a small package

- Author: Kenneth Lacovara
- Publisher: Simon & Schuster UK
- Price: £8.99 / \$16.99
- Release date: Out now

Hardly reaching 160 pages, this small, rather unassuming-looking book packs more awe-inspiring revelations into its short pages than some multi-volume epics.

In *Why Dinosaurs Matter*, palaeontologist Dr Kenneth Lacovara makes an astonishing and convincing case for dinosaurs as the real masters of adapting to life on planet Earth, showing us how we can learn a great deal from them and even convincing us they still exist, right in our forests and gardens and all around the world.

The book is split into easily digestible chapters, each dealing with a specific aspect of dinosaur



history, and perhaps even more importantly, our history of unveiling their secrets at an ever-increasing pace. Lacovara is a masterful writer, his text authoritative yet inherently approachable and easy to read. He doesn't dumb anything down yet he can make concepts of palaeontology palatable to even a complete novice.

*Why Dinosaurs Matter* can easily be read in a single sitting but will be picked up again and again for the sheer pleasure of reading it.



## The Periodic Table

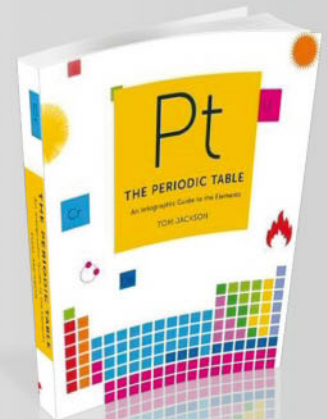
A visual guide to the elements

- Author: Tom Jackson
- Publisher: Aurum Press
- Price: £20 / \$29.99
- Release date: Out now

The periodic table is one of the most remarkable and instantly recognisable scientific breakthroughs. Science writer Tom Jackson offers a refreshing approach, combining cutting-edge science with visually stimulating infographics in this superb book.

In his introduction, Jackson explains how the periodic table presents the fabric of the universe. It is the ultimate infographic, detailing every element that exists on Earth and their unique atomic structure. He expertly explains the different element categories and the properties that tie them together or separate them.

Jackson makes a dry and challenging subject engaging and



accessible by using simple, colourful diagrams. He explores every element individually (both naturally occurring and human-made), revealing its complex structure and properties. The science is intermingled with the ordinariness of everyday, examining the elements' surprising uses and the stories of their (often accidental) discovery.

*The Periodic Table — A Visual Guide to the Elements* is a must-read for science-lovers and science-loathers alike as it makes the subject both comprehensible and fun, which is no mean feat.



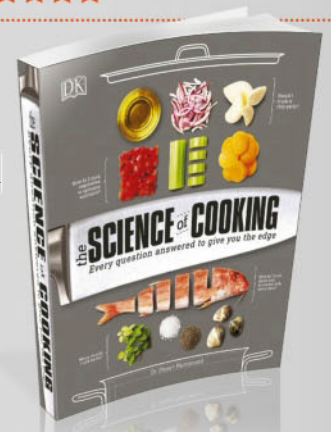
## The Science of Cooking

How to turn your kitchen into a laboratory

- Author: Dr Stuart Farrimond
- Publisher: DK
- Price: £20 / \$30
- Release date: Out now

Fearlessly whisking together scientific chemistry and the art of cooking, *The Science of Cooking* sets out to prove that there's hard data behind those supposedly intangible feats of making delicious food. And in many ways it succeeds.

The book is a classic DK title, with an encyclopaedic approach to its subject, covering everything from the basics of how our taste buds work to the specific science behind cooking at different temperatures and what chemical effects occur with the application of salt or other spices right through to every possible type of food.



This is complemented with an array of beautifully designed infographics, annotated illustrations and yes, a great number of practical cooking tips. While everyone has different methods in the kitchen, where some take great pleasure in detail and accuracy, others swear by a more 'freestyle' approach to cooking. *The Science of Cooking* should be a useful reference guide to anyone interested in how making great food really works.



## Wordsearch

C	N	I	E	M	A	M	M	A	L	S	L	B	T	S
P	E	D	V	S	D	I	O	R	D	O	E	R	E	B
A	B	I	Y	Y	R	V	A	U	Q	S	P	O	X	M
T	U	B	B	E	T	E	W	N	R	M	H	U	I	P
A	L	T	A	L	I	F	E	O	Y	S	E	R	S	A
G	A	V	R	E	R	T	H	T	F	C	E	T	M	M
O	R	A	E	A	M	N	Y	O	U	T	A	E	Q	U
T	V	R	F	M	A	U	O	R	P	R	L	W	A	A
I	Y	H	O	J	K	I	U	N	W	Y	T	H	E	R
T	K	X	O	L	O	Q	W	A	R	H	T	C	E	T
A	X	R	T	H	L	M	R	D	T	I	Q	A	B	T
N	T	G	Y	G	I	S	O	O	E	S	D	E	E	S
B	M	U	E	C	A	N	A	R	Y	N	Y	L	T	A
O	V	T	O	B	O	R	W	R	E	U	N	B	C	K
I	G	R	Y	E	J	H	I	C	E	C	O	R	E	S

**FIND THE FOLLOWING WORDS...**

DYE  
GUT  
SEEDS  
SHOES  
ROBOT  
BLEACH  
TRAUMA  
MAMMALS  
TORNADO  
ICECORES  
STARWARS  
BAREFOOT  
PATAGOTITAN  
TROJANHORSE  
NEBULA  
LIFE  
CANARY  
DROIDS

## Star Wars quickfire questions

**Q1** How fast did Han Solo make the Kessel Run?

- ☐ Less than 12 parsecs
- ☐ 14 parsecs
- ☐ Less than 20 parsecs
- ☐ 16 parsecs

**Q2** Where is the Death Star's weak spot?

- ☐ Command sector
- ☐ Thermal exhaust port
- ☐ Canteen
- ☐ Hangar Bay 327

**Q3** Complete the Darth Vader quote

"... I am your father"

**Q4** What colour is Mace Windu's lightsaber?

- ☐ Blue
- ☐ Green
- ☐ Red
- ☐ Purple

**Q5** In which year was *Star Wars Episode III: Revenge of the Sith* released?

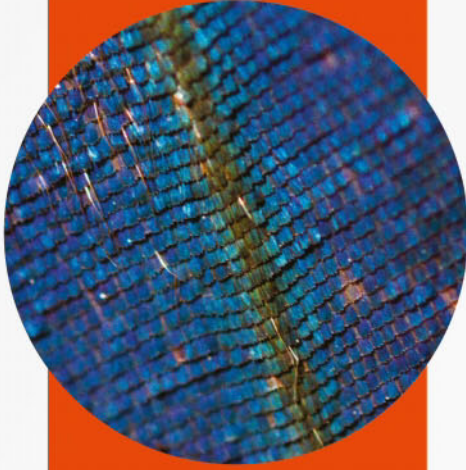
- ☐ 2003
- ☐ 2005
- ☐ 2006
- ☐ 2008

## Spot the difference

See if you can find all six changes we've made to the image on the right



## What is it?



A.....

## Number squares

Complete the grid by multiplying the values in the rows and columns. Time yourself and see if you can beat the team!

x	6	3	4	1	2	8	7	9	5	10
10										
2										
6										
9										
7										
1										
8										
3										
4										
5										

BEAT THE TEAM...



Jackie  
03m 27s



Charlie  
03m 43s



Scott  
03m 21s



Baljeet  
03m 26s



Charlie  
03m 55s



Laurie  
03m 35s

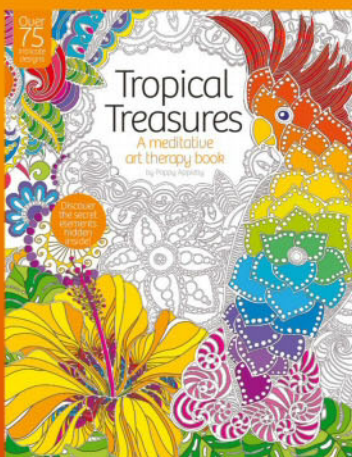


Duncan  
04m 01s

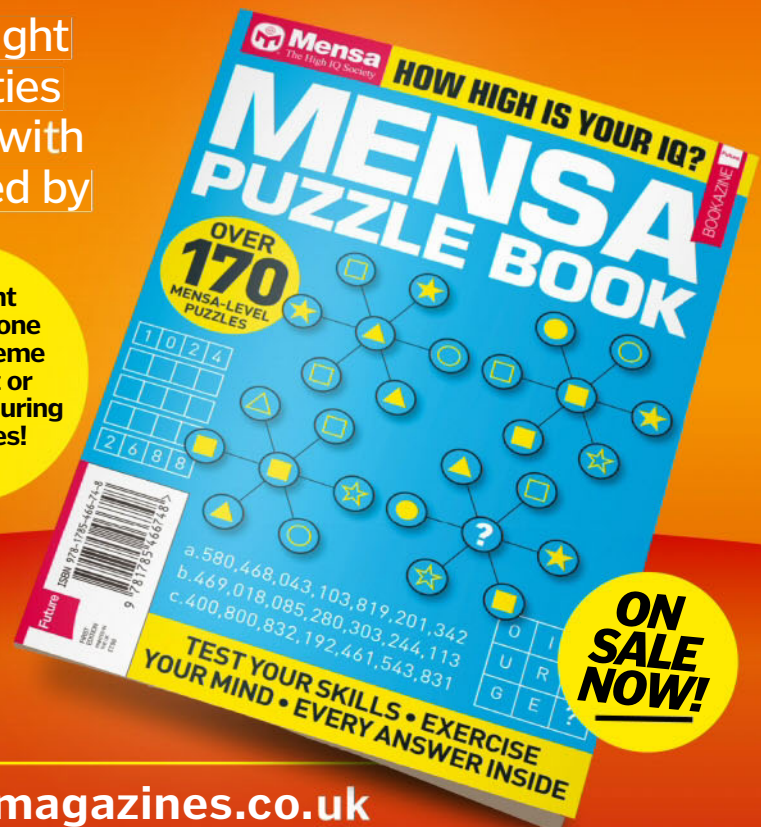
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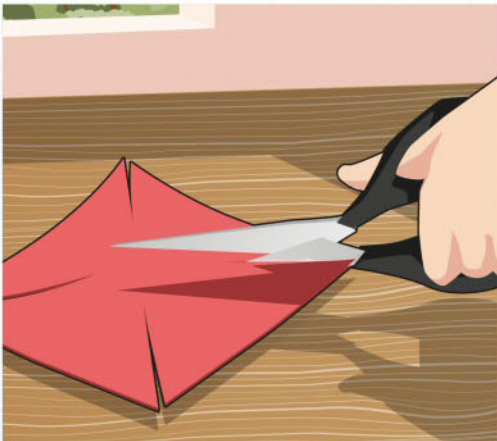


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WITH YOU

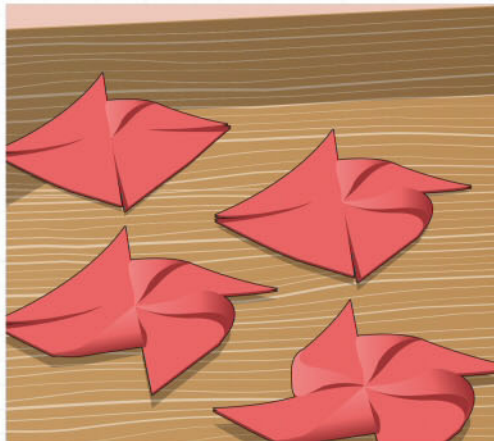
## Make a solar tower

Investigate air density and find out how heat can create power



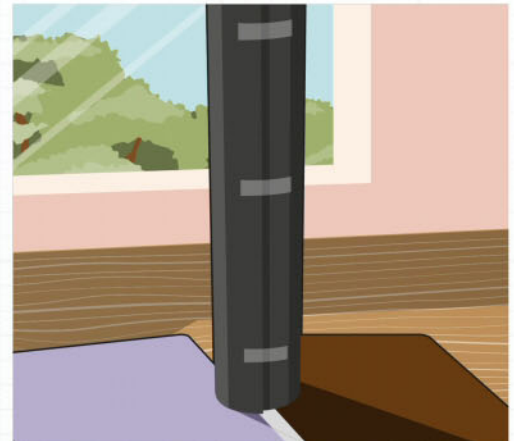
### 1 Make your fan

You'll need a rectangle of black card around 30 centimetres long and 25 centimetres wide. You'll also need a piece of paper, some scissors, a long pin, two similarly thick books and a small strip of card. Once you have these items, cut a square of paper ten centimetres wide, then make a cut from each corner towards the middle of the square, around two-thirds of the way to the centre.



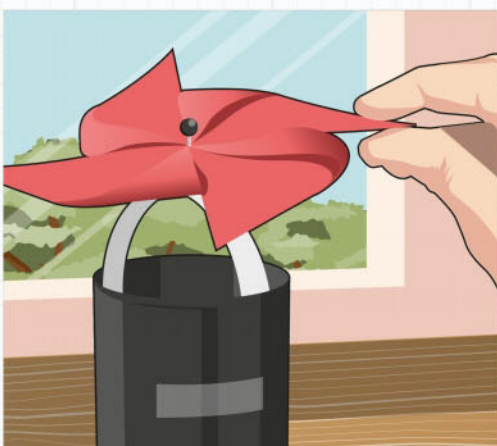
### 2 Fold it

Now for the slightly fiddly part. Take one corner of the paper at a time and fold it in so that it touches the centre point of the square. This will create a kind of 'pocket' in the paper. Do the same with the other three corners, ensuring that these pockets all face the same direction, like the blades of a fan. Glue the folded paper in place at the centre of the square.



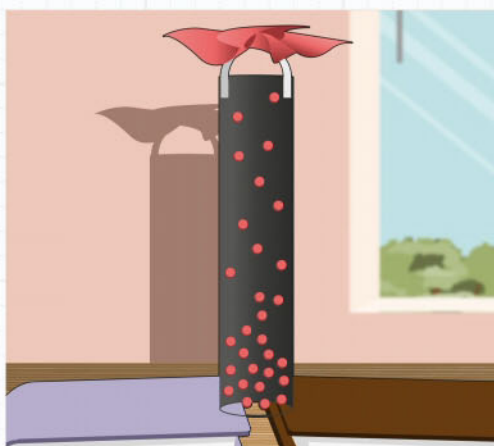
### 3 Create your tower

Next you need to create the solar tower. Take your black card and roll it into a cylinder shape — this will be the shape of your tower. Now take the two books you selected earlier and place them a few centimetres apart on a flat surface, then place your cylinder over the gap. This will allow air to enter the tower from the bottom and circulate up through the tube.



### 4 Add your fan

Take a small strip of card and bend it slightly to create a C-shaped piece. Stick this to the top of your tower on the inside to create a loop that looks a little bit like a handle for your cylinder. Then push the pin about half way through this strip of card and tape your fan on top of the pin so that it sits just above the tower's opening.



### 5 See your solar power in action

Now place your tower near a sunny window to see what happens. Black items absorb heat, so by using black card you have created a tower that warms up the air inside it. What happens at it gets hotter? You should see that the fan on top starts to move as air is pushed up through the tube and cooler air is pulled in from the bottom.

*"Black items absorb heat, so by using black card you have created a tower that warms the air inside it"*

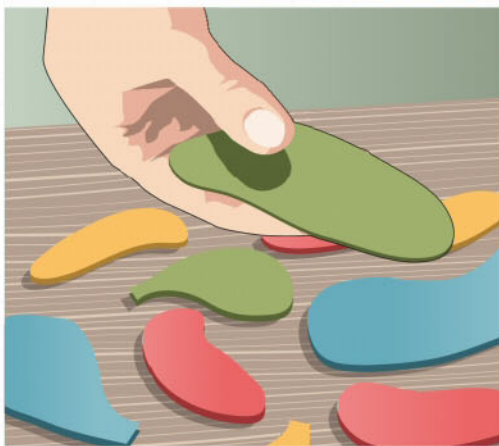
#### In summary...

When the heat absorbed by the black tube is passed onto the air inside the tube, the air becomes less dense (lighter) and starts to rise. As it moves up through the tower and out of the top it makes the fan spin!

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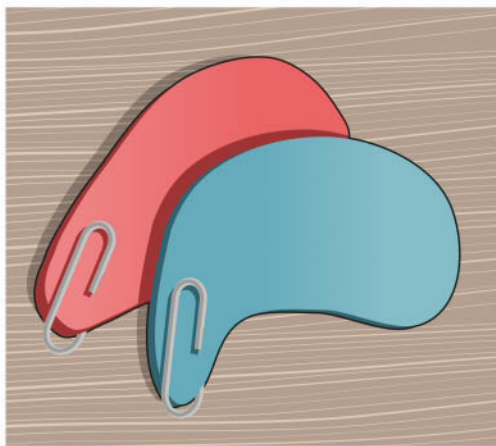
# Make sycamore helicopters

See the science behind the seeds that help sycamore trees reproduce



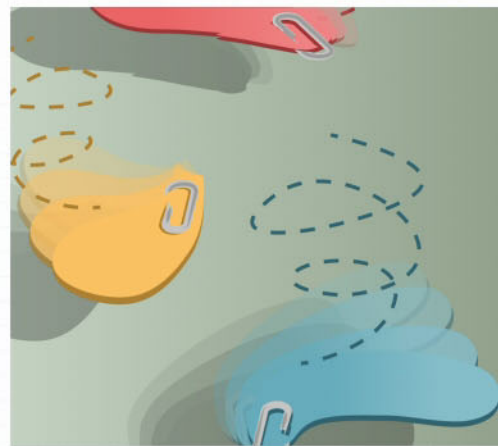
## 1 Create your shapes

To get started you'll first need to cut out different shapes from thick paper or card. Try to cut the shapes in a range of sizes, from around two to six centimetres — if you can use different coloured card for each one it will make it easier to tell them apart. When you throw them later, you'll be able to test the different shapes to see which one works best. You can also write numbers on the shapes to help you tell them apart.



## 2 Add the weight

Next, attach a paper clip to the narrow end of each shape. If you look at a real sycamore seed you'll see that the seed itself is found in one end of the shape, with the rest of the structure dedicated to a fan-like blade that helps the side to float and fly. By adding weight to the thinner end of the shapes you've made you're creating a similar structure, which should fly in the same way when you test it.



## 3 Throw and test

You can throw your helicopters into the air or drop them from a high place like an upstairs window. Which shape is the most effective when they drop? Make a note and try to work out why different shapes work better than others. For some of the shapes you might need to bend the paper slightly to get the shape to spin well as it falls — this is just like real sycamore seeds, which have slightly curved blades.

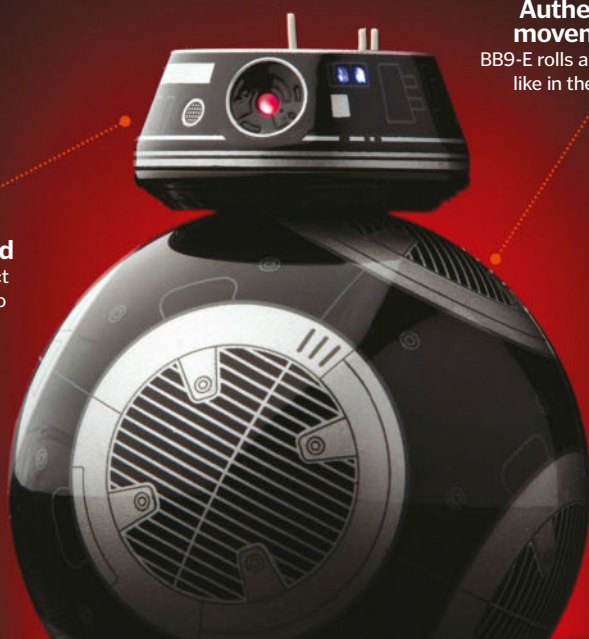
### In summary...

When a sycamore seed falls from a tree the air pushes up against the blades, bending them up. When air pushes upwards on the slanted blades the seed moves sideways, making it spin. If there is a big gust of wind the seed can be carried off to somewhere suitable for it to grow.

**NEXT  
ISSUE**  
MAKE A  
BUBBLE BOTTLE  
CREATE A SINGING  
BIKE TYRE

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- a) **The Blasted Jedi**
- b) **The Masked Jedi**
- c) **The Last Jedi**

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THE ROOM**  
Discover the 'science-y stuff  
staring you in the face' with  
this fascinating and hilarious  
book from authors Steve  
Mould and Helen Arney.

### Letter of the Month

## Sneezing in the sunlight

Dear HIW,  
I've been reading your magazines lately and I have really enjoyed them. I was just wondering if you could answer a question. Why do some people sneeze when they see a bright light?  
Many thanks,  
Pascal Ahearne, aged 12

Sneezing when exposed to bright light is known as a photic sneezing reflex (PSR). It is also known as — and this isn't a joke — ACHOO syndrome (Autosomal dominant Compelling Helio-Ophthalmic Outburst). It's not exactly clear as to why it

PSR may be caused by mixed messages between nerves

occurs, but we know the act of sneezing itself is a protective reflex to clear the nasal passage. There are some theories as to why light could inspire a sneeze.

Some scientists have suggested that 'cross-talk' between the nerves that control sneezing and vision leads to interference between the different impulses and therefore triggers the PSR. Though it is unclear as to why this occurs, it seems to be hereditary.

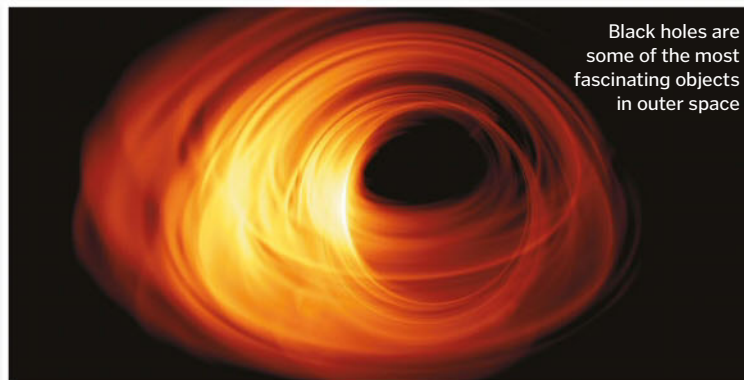
So chances are, if your parents sneeze in the sunlight, you are likely to as well. Grab a tissue before you step outside on bright days!



## Are black holes real?

Hello HIW,  
It has been over two years since I got my first issue and I have been reading it ever since. I have been thinking a lot about black holes recently and was wondering, if light can't escape from them, how do we know that they even exist? Are we even 100 per cent sure that they exist?  
Best regards,  
Zac Lovat, aged 11

That is a great question Zac! The answer to this is very complex, but in short we can predict that black holes exist because of the influence they have on objects around them, such as their gravity and the radiation they emit.



Black holes are some of the most fascinating objects in outer space

There are projects such as the Event Horizon Telescope that are working to take a picture of the border of a black hole when it

devours a star, known as the event horizon. Check out our previous issue to find out more about the mysterious world of black holes.

Amazon river dolphins are one of seven freshwater Cetacean species



## Differences in dolphins

Dear HIW,  
What is the difference between river dolphins and normal dolphins?  
Jacob Gibson, aged 10

Dolphin species that are categorised as river dolphins have an affinity to fresh water. Unlike marine dolphins swimming in seas and oceans, river dolphins inhabit rivers of South America and Asia. These dolphins have physical differences to their marine cousins, such as elongated snouts and rounded foreheads.

Some species of river dolphin can survive in salt water too, but other species, such as the Amazon river dolphin, are only able to survive in fresh water.

What's happening on...

## social media?



This month we asked our followers what their favourite *Star Wars* vehicle is and why...

"74-Z speeder bike. It's like a motorbike but without wheels. Imagine off-roading without the fear of punctures!"

@RSTTN4

"The LAAT/i [Republic Gunship] because of its multi-purpose use in the Clone Wars"

@Maverick Salvagin

"I would have to agree for first choice, the Republic gunship. A close second would be the humble old TIE fighter. You know the shape off by heart and it's sound is instantly recognisable"

@ Greg Freshville

"It's unconventional, but the Boga that Obi-Wan rides on during his pursuit of General Grievous was super fun and makes a great noise!"

@ laurenuy

"I'd go classic. Millennium Falcon. Has been through a lot but still handles amazingly"

@ ErlingurEinars

# HOW IT WORKS

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**1,000**

THE AVERAGE NUMBER OF TORNADO  
EVENTS EACH YEAR IN THE US

**1947** THE FIRST TIME  
A DEFIBRILLATOR  
RESTARTED A HUMAN HEART

**5,500**

The recognised  
different species  
of mammal  
alive today

**300 TO  
500**

THE AVERAGE NUMBER OF  
BACTERIAL SPECIES IN THE  
GASTROINTESTINAL TRACT

**2.6  
MILLION**

INDUSTRIAL ROBOTS ARE  
EXPECTED TO BE DEPLOYED  
WORLDWIDE BY 2019

**815  
LIGHTYEARS**

The distance of the Pencil  
Nebula from Earth

**4 MILLION**  
THE NUMBER OF  
MAPS THE BRITISH  
LIBRARY HOLDS

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physiologically  
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THE LENGTH OF THE  
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PLATFORM SHOES WERE ONCE WORN BY GREEK  
ACTORS TO SHOW THEY WERE OF HIGH STATUS



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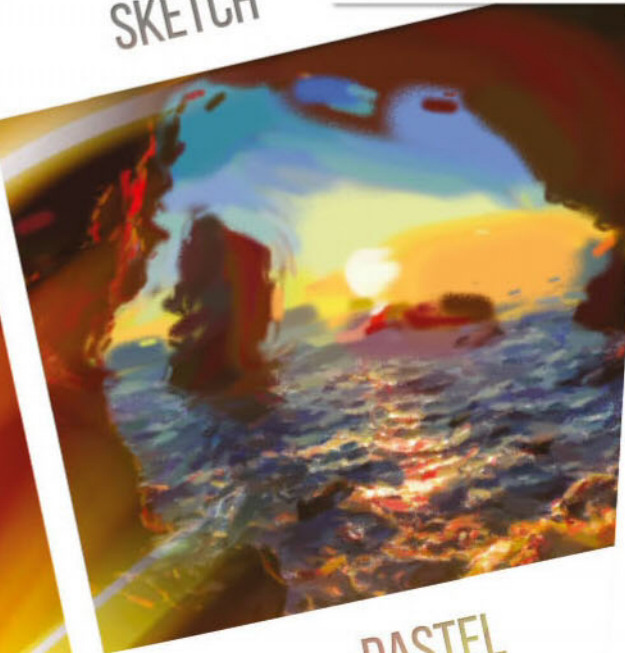
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